

2015

# Yellowknife Geoscience Forum



Abstract and Summary  
Volume

**Cover photograph**

Low water levels in NWT;  
Val Jackson, recently retired from the Northwest Territories Geological Survey

The picture was taken near the Hornaday River and shows ripples in silt to mudstones of the upper Nelson Head Formation of the Neoproterozoic Shaler Supergroup, Brock Inlier

**Compiled by D. Irwin, P.X. Normandeau and S.D. Gervais,**

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## Abstracts - Oral Presentations

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### A 2015 GEOPHYSICAL UPDATE FOR KENNADY NORTH PROJECT, NT.

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This presentation will provide an update of geophysical surveys performed in 2015. These surveys were undertaken to aid in the delineation of known kimberlites and discovery of potential kimberlite targets on Kennady Diamonds Inc.'s Kennady North Property.

In 2015, Kennady Diamonds Inc. focused most of their geophysical budget on expansion of the known kimberlites. Previous OhmMapper surveys were expanded in the Doyle & MZ Areas in order to provide locations for exploration drilling. Ground based Gravity surveys were completed using an increased sample density in key areas. This increased density in the gravity data proved to be very helpful in the detailed drilling of the Kelvin and Faraday kimberlite bodies.

Late in the summer season, a small scale marine seismic system was utilized on the Kelvin and Faraday lakes. This data will hopefully be used to discover potential areas of new or thicker kimberlite under the lake. As the Kelvin and Faraday kimberlites are not the typical pipe-like bodies, many different geophysical tools from our toolbox must be utilized.

### NUNAVUT 2015: EXPLORATION OVERVIEW

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Mining and mineral exploration companies continued to be active in Nunavut in 2015. Spending intentions for mineral exploration and deposit appraisal reached nearly \$175 million, up from estimated expenditures of \$145 million in 2014. Senior companies' estimated spending intentions were \$101 million, a 35% increase over 2014; in a more modest increase, junior companies estimated spending at \$73 million, which is still an improvement over last year's \$69.8 million (NRCan February 2015 estimates).

Gold continues to be the commodity of primary interest in Nunavut, accounting for almost three-quarters of all estimated exploration expenditures. Agnico-Eagle's Meadowbank gold mine produced 179,799 ounces of gold in the first half of 2015. At the company's Meliadine gold project, work continued on extending the underground ramp, and an Inuit Impact Benefit Agreement was signed with the Kivalliq Inuit Association. At its Amaruq project, AEM completed over 75,000 metres of drilling and released an Inferred Resource Estimate of 2 million ounces of gold. TMAC Resources continued underground development of the Doris deposit and drilled over 18,000 m at the Madrid North, Nartok, and Suluk deposits to better delineate their mineralization and to take samples for metallurgical analysis. After its successful acquisition of 100% of North Country Gold and its Committee Bay project, Auryn



Resources added to the tenure on that project with the staking of over 158,000 hectares of claims, bringing the total tenure to over 217,000 hectares.

Peregrine Diamonds completed an extensive field program that included significant work on the CH-6 and CH-7 kimberlites. A bulk sample was collected from CH-7 using large diameter reverse circulation drilling. Core sampling was carried out on both CH-6 and CH-7, and a total of 3,345 kg of kimberlite material was sent for microdiamond analysis. North Arrow Minerals reported its diamond valuation results from last year's bulk sample at Qilalugaq in June and completed till sampling at its Mel property in September.

The first shipment of iron ore left Baffinland's Mary River mine in August for processing in Europe. The company has also applied to the Nunavut Impact Review Board for a change to the mine's project certificate that would allow it to increase tote road traffic and ship more ore at Milne Inlet; a decision from NIRB is pending.

Base metals saw limited activity in the territory this year. Aston Bay Holdings ran a short summer geophysical program at its Storm copper project on Somerset Island in the Qikiqtani region, while Kaizen Discovery was active at its Coppermine copper-silver project in the western Kitikmeot.

Although the mining industry as a whole remains in an economic slowdown, the continued presence of advanced, established and early stage projects in Nunavut indicates that the territory remains an attractive destination for exploration and development.

## **REGULATING CLIMATE CHANGE MITIGATION & ADAPTATION NORTH OF 60**

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New northern mines are designed with climate change in mind. The signs and effects of climate change are clear in Canada's north. The Northwest Territories government has spent more than \$140 million in the last two years responding to problems linked to global warming and there is no end in sight. Canada's new government was elected with a commitment to take immediate action on climate change. New legislative and policy initiatives are likely. Consideration will be given to the extent to which federal laws or programs should or must play a role in addressing climate change in the North.

This presentation will review the legislative and regulatory status of the three territories relating to mitigation and adaptation to climate change. Gaps in territorial legislation to address air quality including greenhouse gases and other territorial government mechanisms will be discussed. The presentation will also canvass other possible solutions with a focus on mining activities. We will review the legislative and regulatory responses of other jurisdictions such as Alaska and Finland. Included in this analysis is an evaluation of the role and effectiveness of guidelines setting out best practices and procedures as a way addressing the rapidly evolving and changing effects of climate change in the North.

## COMMUNITY-BASED AQUATIC EFFECTS MONITORING PROGRAM IN THE MARIAN WATERSHED (Tłchq GOVERNMENT)

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Tłchq 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 Tłchq people.

Tłchq Lands have been under Moratorium since the signing of the Tłchq Agreement in 2005 and on June 1, 2013, the Moratorium was lifted as the Tłchq Wenek'e or Land Use Plan came into force. With the potential for future development of Tłchq Lands, the Tłchq 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 Tłchq lands and in locations the Tłchq feel are the most important, prior to any major development pressure (such as the NICO mine by Fortune Minerals), 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 K'eàgotì (Hislop Lake), upstream of the planned NICO Mine site, in the fall of 2013. This project included the training of eight 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 as well as 2015 in order to bring back the results from the K'eàgotì (Hislop Lake) camp as well as Behtsotì (Shoti Lake) 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 K'eàgotì (Hislop Lake) to Marian Lake, which will be visited on a four-year cycle.

The DCLP organized the third field program this fall at Marian Lake near Marian Village. 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 Tłchq waters by Tłchq people, and prioritize meaningful communication back to community members. A results workshop will be scheduled for the spring of next year.

## EKATI DIAMOND MINE UAV'S

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Dominion Diamond Ekati Corporation (DDEC) purchased two unmanned aerial vehicles (UAV's) in 2014 to assist in surveying the active open pits and kimberlite stockpiles at the mine. UAV technology has allowed the team to survey various aspects of the mine in a safer and more accurate

manner. Along with making day to day work more efficient, DDEC surveying now has the ability to complete various other requests from departments at the mine. These include; large area photographs of lay downs, new road alignments, projects and environmental areas of interest.

## **NORTHWEST TERRITORIES GEOLOGICAL SURVEY – MINERALS AND BEDROCK MAPPING – 2015 ACTIVITIES**

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The Northwest Territories Geological Survey (NTGS) carries out government geological survey activities for the Government of the Northwest Territories (GNWT). Within the NTGS, the Minerals Deposits and Bedrock Mapping (MDBM) carries out geological, geochemical and geophysical research to enhance our knowledge of NWT geology.

MDBM draws research funding from a variety of sources including core “A-Base” funding, targeted GNWT Mineral Development Strategy funds and federal Strategic Investment in Northern Economic Development funds from the Canadian Northern Economic Development Agency (CanNor).

MDBM is mapping freshly exposed volcanic rocks, cleaned by forest fires, to test their potential to host undiscovered Volcanic Massive Sulphide deposits. This detailed mapping serves as a framework for geochemical and stratigraphic mineral deposit studies. Multiple metallogenic and thematic studies are also underway to elucidate the tectonic history and mineral potential of the East Arm.

In the Cantung area, a stream sediment sampling program was completed to follow up on excellent indicator mineral results obtained in an earlier survey. MDBM piggy-backed several graduate student research projects with the stream sediment program.

Industrial Mineral research continues to present lucrative, often low capital cost, investment ideas. This year efforts focused around artisanal salt opportunities in the Dehcho and Akaitcho, as well as progress on an NWT Atlas of Industrial Minerals.

Diamond Mining continues to drive the economy of the NWT so it is no coincidence that the MDBM is conducting several diamond related research initiatives. These activities included projects to explain occurrences of, and characterize the potential for diamonds in frontier areas. Additional diamond related projects aim to characterize the mantle beneath, and physiochemical conditions of, known diamondiferous kimberlites.

CanNor funds allowed the completion of a research program studying the surficial geology of the central Slave Province diamond fields. The program utilized drilling, surficial mapping, geophysics and a host of innovative tools to model indicator mineral entrainment, develop new 3D surficial material maps and contribute to glacial transport models for use by industry diamond explorers. This program included a permafrost component to advise the development of infrastructure in the region, and monitor the lands response to climate change.

The addition of a geophysicist to the MDBM has enabled us to organize, understand and maximizing the utility of our publically available geophysical collection

as well as to add a geophysical component to many of our field research projects.

MDBM conducts collaborative projects with Natural Resources Canada Geoscience for Energy and Minerals research programs. These programs include; mapping in the Brock Inlier, mapping and lake sediment sampling in the Churchill Province, indicator mineral research on Banks Island, and the development of new indicator mineral and indicator mineral chemistry techniques for mineral deposits in the Wopmay Orogen.

MDBM oversaw the construction of the Geological Materials Storage Facility, a warehouse and examination facility for NTGS geological collections. The MDMB also initiated the first year of a two year core rescue program.

## **INTO THE UNKNOWN: SURFICIAL GEOLOGICAL INVESTIGATIONS IN THE SOUTH RAE, NORTHWEST TERRITORIES**

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The Geological Survey of Canada, as part of its Geo-Mapping for Energy and Minerals Program (GEM2), in partnership with the Northwest Territories Geological Survey, has begun a three-year (2015-2017) project to upgrade the bedrock and Quaternary geoscience knowledge for the underexplored and predominantly drift-covered South Rae region in southeastern Northwest Territories. Little is known with respect to the surficial geology in this region and as a result, the

Quaternary framework necessary for the implementation of successful mineral exploration, sustainable resource development and land-use management is lacking. In order to address this knowledge gap, the Quaternary geological component of this project will: 1) increase the surficial mapping coverage; 2) define the regional drift composition and glacial transport characteristics; and 3) reconstruct the glacial history and ice-flow sequences, particularly as they relate to the central Keewatin Ice Sector and migrating ice divides.

During the 2015 field season, surficial geological mapping and regional till sampling were completed in NTS map sheets 75A and B. Targeted reconnaissance sampling, focused primarily on 4 transects, resulted in till samples collected at 88 sites for provenance, geochemistry, indicator minerals and gold grains. Multiple small and meso-scale erosional ice-flow indicators (e.g. striations, grooves, roches moutonnées) were measured at 55 locations. To help establish a minimum age for deglaciation in this area, 2 beach sand samples and 1 basal peat sample were collected for respective optically stimulated luminescence and radiocarbon dating.

Preliminary mapping has identified at least 4-5 phases of ice flow with 3 main flowsets variably affecting the study area. The oldest regional ice flow was to the south (pre-last glacial maximum (LGM) ?). The main regional ice flow, comprised of 2 flowsets (LGM and deglaciation) was generally to the southwest. A younger, late stage, west flowing paleo-ice stream overprinted this southwest flow in the northern part of the study area. Rare SSE/NWW trending ice flow indicators were noted but their relative age is unknown. Distinctive erratics, such as Dubawnt Supergroup lithologies, are derived from sources located at greater than

200 km to the north-northeast and suggest sustained transport and dispersal of glacial debris by the older southward flow.

Drift cover of variable thickness is extensive, ranging locally from 40 to 100% coverage. The dominant surficial material is till of varying composition, thickness and depositional environment. The landscape, particularly in map sheet 75B, is dominated by streamlined landforms with organic terrain in the lows. Numerous parallel subglacial meltwater corridors trend WSW-SW (>200km) across the map area with two types of signature landform/sediment assemblages: 1) eskers and parallel trains of either ice-contact glaciofluvial (hummocks and ridges) deposits or terraced glaciofluvial deposits, and 2) trains of hummocky till (generally a product of erosion), boulder lags with small discontinuous eskers and related deposits. New mapping indicates proglacial lakes were more extensive in this area than previously thought.

## **COPPERMINE RIVER BASIN HYDROLOGICAL MODELLING IN SUPPORT OF JAY PROJECT ENVIRONMENTAL ASSESSMENT**

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A water balance model was developed to provide a baseline and to assess the effects of the Dominion Diamond Jay Project on lake water levels and outlet discharges in the Lac du Sauvage, Lac de Gras and

Desteffany Lake basins, in the Coppermine River basin.

The water balance model was developed to allow the surface hydrology be characterized on a finer spatial scale over a broader region and time period than represented by historical or site-specific data. It allowed changes to be evaluated for waterbodies with limited or no gauging data, with consideration of long-term natural variability. Existing hydrometric data were supplemented by an intense, short-term field program. Due to project time constraints, the model was developed within six months of the start of baseline studies.

The model was developed using GoldSim™ software and used a meteorological daily time series from 1959 to 2013, derived based on local and regional data. Lake outlet characteristics were derived from hydrometric field data and model parameters were calibrated to site-specific data in the Lac du Sauvage and Lac de Gras basins. Runoff coefficients were calibrated to the mean annual water yield of a hydrometric station on the Coppermine River. Frequency analyses performed for key nodes provide a derived historical baseline of lake stage and discharge regimes.

Qualitative model validation was performed based on short-term hydrometric data from Lac de Gras and from three tributary lakes in the Lac du Sauvage basin. Quantitative model validation was performed using additional data from a hydrometric station on the Coppermine River, not used during the calibration. Using a quantitative statistical evaluation, model performance was assessed as satisfactory in terms of predicting the timing and magnitude of flows and water levels.



Jay Project effects, including changes to lake water levels and lake outlet discharges, were modeled by modifying the baseline model to consider project infrastructure and water management activities. Effects to surface hydrology were predicted for construction (including the dewatering period), operations, and closure phases of the Project, and the post-closure period. The main focus of the assessment was the effect of major Project activities (e.g., dewatering, diversions, operational water management, back-flooding in closure) on discharge and water levels at the outlets of Lac du Sauvage, Lac de Gras, and Desteffany Lake, as compared to baseline conditions.

The water balance model provided a satisfactory basis for environmental assessment and project design. However, uncertainties exist for some model nodes and are currently being addressed by a supplemental hydrometric program.

**DEVELOPMENT OF  
GEOCHEMICAL  
EXPLORATION  
TECHNOLOGIES FOR THE  
DISCOVERY OF CONCEALED  
KIMBERLITES UNDER  
GLACIAL OVERBURDEN, NWT.**

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Attention is being focused on the development of deep penetrating geochemical exploration methods as the discovery rate of world class deposits decreases. Diamondiferous kimberlites

located in the Lac de Gras region of the Northwest Territories are one of the many deposit types in Canada covered by glacial overburden, and are therefore challenging to detect. This paper presents initial results from an investigation of the DO-18 kimberlite (Peregrine Diamonds), buried under 5-20m of glacial cover, to identify surface geochemical responses directly related to the buried kimberlite and differentiate between physical and chemical transport mechanisms.

A detailed grid of 150 samples over an area of 0.5km<sup>2</sup> sampled the oxidized upper B soil horizon in till above and off the DO-18 kimberlite into background. Regolith mapping was conducted and included surficial soil type and rock fragments, topographic variation and physical features, e.g. bogs, swamps, vegetation and glacial direction indicators. This allows an assessment of surface controls on the geochemistry, including the generation of false anomalies from chemical traps such as swamps. Multi-element geochemistry comprising 4-acid, Aqua-Regia and distilled water extraction coupled with ICP-MS was undertaken using commercial techniques to identify and differentiate between those elements migrating by chemical process from those migrating by physical transportation. Hydrocarbons were analysed using the SGH-technique (ActLabs) and the Gore-sorber technique (AGI) to characterize type and abundance of complex hydrocarbons above the kimberlite relative to the host granite gneiss. Preliminary results from the 4-acid digestion data show a clastic dispersion of Nb, Ni, Mg, Co, Cr and Cs from directly above the kimberlite to the edge of the sampling grid 500 metres northwest of the buried kimberlite. Surface material exhibits a strong control on geochemistry with trace elements being controlled by major elements (Al, Fe, Mn)

found within each surface material type, and in some cases are heavily influenced by the presence of organic carbon. Evaluation of these relationships allows clarification of the natural background noise and enhancement of the geochemical responses and contrasts.

## TOWARDS SUSTAINABLE MINING

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This presentation will introduce the Mining Association of Canada's (MAC) award-winning Towards Sustainable Mining (TSM) initiative. The presentation will summarize the business case for TSM, the program architecture and describe how the different components of the program are applied at mining facilities across Canada and abroad. TSM is the only mining specific standard that includes facility level annual public reporting and independent verification. The presentation closes with a review of the results from the soon to be released 2015 TSM Progress Report, demonstrating the measurable progress made by the industry since verified reporting began in 2006, and a summary of some of MAC's other priorities such as transparency of payments to governments from Canadian mining companies.

### About TSM

The TSM initiative is MAC's commitment to responsible mining and participation in the program is mandatory for our members. It is a set of tools and indicators to drive performance and ensure that our members are doing the right things for the right reasons at each of their facilities. Adhering to the guiding principles of TSM, mining companies demonstrate leadership by:

- Engaging with communities
- Driving world-leading environmental practices
- Committing to the safety and health of employees and surrounding communities

Today, communities expect more of mining companies and the industry expects much more of itself. TSM helps mining companies meet society's needs for minerals, metals and energy products in the most socially, economically and environmentally responsible way. At its core, TSM is:

**Accountable:** Assessments are conducted at the facility level where mining activity takes place – the only program in the world to do this in our sector.

**Transparent:** Members publicly report their performance against 23 indicators annually in MAC's TSM Progress Reports and results are externally verified every 3 years.

**Credible:** TSM is overseen by an independent Community of Interest (COI) Advisory Panel, which shapes the program for continual advancement.

## **OPPORTUNITIES AND OBSTACLES: KEYS TO ENERGY PRODUCTION IN NORTHERN CANADA**

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A non-technical talk highlighting the opportunities that await northerners and the various obstacles standing in their way. Ideas and thoughts around unlocking those opportunities and removing those barriers will be presented in a provocative and interactive way.

## **CARIBOU RELEVANT ENVIRONMENTAL CHANGES AROUND THE EKATI DIAMOND MINE MEASURED IN 2015**

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How would a large open pit mine on caribou range (e.g., the Ekati Diamond Mine in the Bathurst caribou's summer range) have influenced caribou? A traditional knowledge study on the cumulative impacts on the Bathurst caribou herd qualitatively described how mining activities might have influenced

the herd (Mackenzie et al. 2013): caribou migration routes deflected away from the mines probably due to seeing mining activities or hearing the noises; and skinny caribou or abnormal smells and materials in caribou meat, liver, or the hide linings probably related to changes in caribou forage and quality of water and air. In other words, the potential influences of mining operations on caribou were most likely through altering what caribou can see, hear, smell (e.g., dusts and fine particle matter < 2.5 µm (PM2.5) in the air, and from acidity in the soil), and taste (e.g., dust on foliage, vegetation composition change). Boulanger et al. (2012) estimated the size of a zone of influence (ZOI) of the Ekati-Diavik mining complex in the Bathurst caribou summer range, using caribou presence dataset. They also explored the mechanisms of ZOI using the spatial distribution of the total suspended particles, which was simulated with an atmospheric transport and dispersion model (Rescan, 2006).

While these studies have added to our understanding of the possible impacts of mining operations on caribou, knowledge gaps remain. One outstanding gap is the lack of direct measurements about the caribou relevant environmental changes caused by mining operations. For example, exactly from how far away can caribou clearly see the vehicles driving on a mining road, or the buildings and the elevated waste piles in a camp? From how far away might caribou hear the noise caused by mining operations? To what spatial extent had the dusts and PM2.5 from mining operations influenced the tundra ecosystems? And how the dusts and PM2.5 from mining operations might have influenced caribou forage quality? Potentially these questions can be answered by in-situ measurements and satellite remote sensing. For example, studies have showed that it is possible to remotely sense PM2.5



distribution using twice-daily MODIS data at a spatial resolution of 1 km (Lyapustin et al., 2011; Chudnovsky et al., 2013; Hu et al., 2014). The objective of this study is thus to quantitatively measure these changes around the Ekati Diamond Mine, by means of in-situ surveys and satellite remote sensing.

We conducted field surveys at more than 100 sites around the Ekati Diamond Mine during August 14-23, 2015, a collaborative effort of the NWT CIMP project entitled “Satellite Monitoring for Assessing Resource Development’s Impact on Bathurst Caribou (SMART)”, and the Dominion Diamond Ekati Corporation. In this presentation, we will report preliminary results and lessons learned from our first year’s study.

## TRACKING THE ENVIRONMENTAL FATE OF LEGACY MINING POLLUTION IN YELLOWKNIFE BAY, GREAT SLAVE LAKE

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Yellowknife Bay on Great Slave Lake is a water body of cultural, subsistence and recreational importance for the Yellowknives Dene First Nation and residents of Yellowknife. The ecosystem

health of Yellowknife Bay has been impacted by releases of pollution from gold mining since the 1940s. Although environmental monitoring has been conducted on the bay in recent decades, local concerns remain about the long-term fate of legacy mining pollution. Since 2013, we have measured water and sediment quality as well as metal accumulation in the food web to address complex and outstanding questions on the ecosystem health of Yellowknife Bay. We have used specialized field sampling techniques (diffusive gradient in thin film samplers, porewater samplers, dated sediment core profiles) and specialized analytical techniques (lead isotopes, arsenic speciation) to investigate processes controlling the movement and bioaccumulation of legacy metals.

Dated sediment cores show that the greatest inputs of metals to Yellowknife Bay occurred during the initial years of mining operations (late 1940s and 1950s) when few pollution control measures were in place. Significant accumulation of antimony, arsenic, copper, lead, mercury and zinc occurred in sediments at that time. Concentrations of those elements have declined to near pre-mining levels in younger surface sediments, reflecting the burial of legacy pollution after deposition. One exception is arsenic, which is concentrated in younger surface sediment of Yellowknife Bay, indicating that legacy arsenic has been mobile after initial deposition and diffused towards the surface.

Using lead isotopes to trace the spatial extent of mining pollution, we estimate that the zone of atmospheric deposition of metals from ore roasting extended approximately 20 km south of Giant Mine and into the main body of Great Slave Lake. We also estimate that nearly half of the lead currently

accumulating in surface sediment of Back Bay originates from mine pollution, reflecting on-going inputs from the Giant Mine site or lateral transport of legacy pollution within the bay.

In 2014, surface water concentrations of arsenic were relatively low ( $<3 \mu\text{g/L}$ ) in Yellowknife Bay, although levels were four times higher at Back Bay in comparison to the mouth of Yellowknife Bay and the main body of Great Slave Lake. Surface water arsenic was predominantly in the dissolved fraction as arsenate ( $\text{As}^{+5}$ ) although up to 50% of inorganic arsenic was arsenite ( $\text{As}^{+3}$ ) at two sites close to Giant Mine. Bioavailable arsenic (measured using passive samplers) also increased in concentration with proximity to the Giant Mine.

Preliminary results indicate that the exposure of fish to arsenic has declined in Yellowknife Bay in recent decades. Arsenic concentrations in muscle of northern pike are higher than in reference areas but are still relatively low due to the physiological behaviour of this element.

This presentation will highlight preliminary findings on the long-term environmental fate of legacy mining pollution in a northern aquatic ecosystem. These findings are relevant for decision makers who have an interest in the ecosystem health of Yellowknife Bay or who are tasked with predicting and managing environmental impacts of new developments.

## **AN OVERVIEW OF THE REGULATORY FRAMEWORK IN THE MACKENZIE VALLEY, NWT**

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The Land and Water Boards of the Mackenzie Valley regulate the use of land and water and the deposit of waste into water to provide for the conservation, development, and utilization of land and water resources for the optimum benefit for all Canadians and, in particular, for the residents of this region. The key legislation that is used by the Land and Water Boards are the Mackenzie Valley Resource Management Act (MVRMA) and the Waters Act (and their associated Regulations). This talk will give an overview of the regulatory system in the Mackenzie Valley, the key applicable legislation, the land use permitting and water licensing process, regulatory tools that have been jointly developed (including policies and guidelines), and some exciting initiatives that are underway. An update will be provided on how devolution and legislative amendments impact the Land and Water Boards' regulatory processes.

## COOL TOOLS: INNOVATIVE ENVIRONMENTAL MONITORING TECHNIQUES

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Industries face environmental monitoring challenges throughout the lifetime of a project from both regulatory and social (i.e. public approval) perspectives. Conventional approaches and techniques to environmental monitoring may not adequately address site-specific issues or they may not be financially feasible. Here we present some common industry challenges and describe emerging “cool tools” that hold the potential of allowing industry to cost-effectively address pressing regulatory and social concerns around the monitoring of environmental effects. We will discuss the following:

- Techniques to differentiate the effect of one effluent from that of multiple other effluents in the same environment;
- Powerful non-invasive methods for monitoring the presence (and, in some cases, habitat use) of terrestrial and aquatic species, without even having to see any;
- Analytical tools for the differentiation between global and local contaminant exposure in migratory species, such as salmon or birds, to characterize a project-specific contribution to exposure;
- Socially-acceptable, non-invasive approaches to dealing with real versus perceived health risk in situations such as the potential contamination of subsistence foods.

Technology has come a long way in recent decades, particularly in regard to non-invasive and non-lethal approaches to cost-effectively obtaining the same or even

higher quality data. These advances allow us to do things not previously possible – environmental monitoring just needs to catch up! It doesn't have to be expensive, just “cool”.

## THE BUILD IN CANADA INNOVATION PROGRAM, AND NATURAL SCIENCES AND ENGINEERING RESEARCH COUNCIL

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The Government of Canada has several programs in place designed to help Canadian companies grow and move forward. Two Government of Canada representatives will present details on the Build in Canada Innovation Program (BCIP) and opportunities through the Natural Sciences and Engineering Research Council (NSERC).

Public Works & Government Services Canada's Office of Small and Medium Enterprises will present the Build in Canada Innovation Program, which is a program designed to assist Canadian businesses with products and services at the later stages of Research and Development (R&D) move their innovations from the laboratory to the marketplace. The procurement program provides the opportunity for innovators to:

- Sell their pre-commercialized goods and services to the Government of Canada through an open, transparent, competitive and fair procurement process;
- Connect with potential clients in federal government departments and showcase their innovations to them;
- Get feedback on the use of their

innovations in an operational setting before taking them to market.

The presentation will cover the approach of the Build in Canada Innovation Program including how companies can participate in the Call for Proposal, how the proposals are evaluated, how companies become prequalified, and how innovations are matched with a test department. It will feature a demonstration of [buyandsell.gc.ca](http://buyandsell.gc.ca), where participants would gain a level of comfort in finding the Call for Proposal.

Natural Sciences and Engineering Research Council (NSERC) works with companies to help them find solutions and benefit their businesses through a suite of targeted partnership offerings that connect companies to experts at Canada's universities and colleges.

Working with a research team from a university or college can help you achieve business goals, solve problems and get results.

These programs can help:

- Reduce your time to innovate: access world-class knowledge, facilities and students at colleges and universities.
- Address an immediate challenge or a longer-term innovation need.
- Manage costs: NSERC's funding underwrites up to 100% of project costs.
- Identify future hires for your business.

A total of 92% of participating companies report that their NSERC Engage project helped develop a new product or prototype. This presentation would cover the details of these programs.

## **THE COPPERMINE PROJECT – A NEW LOOK AT AN OLD DISTRICT – 2015 EXPLORATION UPDATE**

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Tundra Copper's Coppermine Project is centered approximately 70 km southwest of the Hamlet of Kugluktuk, in the Kitikmeot region of Nunavut. The Project comprises a district-scale exploration target, with tenements covering 3,685 square kilometers of Proterozoic volcanic rocks and overlying sedimentary rocks prospective for volcanic-hosted copper-silver, and sediment-hosted stratiform copper.

Sediment-hosted stratiform copper-silver mineralization occurs at the base of the Neoproterozoic Rae Group. The target horizon is a gently north-dipping dark shale and siltstone overlying red beds and basalt of the Coppermine River Group. This setting is analogous to globally significant copper-producing districts such as the Central African Copperbelt, the Polish Kupferschiefer, and the Keweenaw district, Michigan. Previous work by Cominco in the early 1990s and Teshierpi Mines in the late 1960s intersected stratiform copper mineralization in a series of shallow drill holes over a strike distance of approximately 40 kilometers in the eastern part of Tundra's licences, but little to no follow-up work was conducted in the years following.

Tundra's exploration plan for 2015 was to evaluate this historic work, conduct detailed stratigraphic mapping to develop a modern understanding of key elements of the sedimentary, stratigraphic and structural setting of mineralization, and to test the previously unexplored western extension of

this mineralization at shallow depths, with widely spaced, reconnaissance drill holes.

Tundra's drilling program included seven regionally spaced, relatively shallow, vertical diamond drill holes through the base of the Rae Group, over a strike distance of approximately 40 kilometers westward from the historical drilling, and totalling 1,949 meters. Copper mineralization was intersected in all seven holes, and in most intersections consisted of disseminated copper sulphides (chalcocite, bornite and chalcopyrite).

The last holes of the program, CP15-DD008 and DD009, stepped 17 and 27 kilometers westward, respectively. The final and furthest west hole, CP15-DD009, was collared above a north-south structural block within the underlying basalt-red bed sequence, and was characterized by significantly higher grade and width of mineralization than encountered in previous holes through the Rae Group. From 197.0 meters, hole DD009 returned 29 meters grading 0.57% copper (Cu), including a one-meter interval grading more than 3.04%, and a separate six-meter interval grading 1.06% Cu. The copper sulphides are disseminated, banded, and replaced after interpreted former pyrite nodules, and in thin steeply dipping sulphide and sulphide-calcite veinlets. The copper sulphide species within this 29-meter intersection are vertically zoned from chalcocite at the base through bornite to uppermost chalcopyrite, with anomalous zinc values overlying the copper-rich zone. Hole DD008 also intersected anomalous zinc mineralization grading 0.18% over 3.11 metres, stratigraphically above a moderately mineralized copper zone (0.26% Cu over 5.06 metres). Zinc mineralization is commonly found laterally to copper in stratiform copper systems, and can be used

to vector towards higher-grade copper in the central parts of such systems.

Tundra's 2015 drilling has doubled the confirmed strike length of mineralized basal Rae Group strata, from approximately 40 to 80 kilometers, and the system remains open along strike. To date, only the shallow, up-dip portion of the gently north-dipping target horizon has been tested along this 80-kilometre strike, and approximately 18 kilometers of down-dip extent remains untested on Tundra's licenses.

## **THE DEVELOPMENT OF REMOTE SENSING TOOLS FOR MAPPING LINEAR DISTURBANCES IN THE SAHTU REGION OF THE NORTHWEST TERRITORIES**

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Boreal regions across Canada are under increasing pressure from human development related to natural resource extraction. Roads, seismic lines, cut blocks, pipelines, and other elements of human disturbance exert cumulative environmental effects that can harm biodiversity, water quality, and the habitat of threatened species such as woodland caribou (*Rangifer tarandus caribou*). The Sahtu region of the Northwest Territories has significant untapped opportunities for natural resource development, including an abundance of



shale oil reserves. Regulatory and government agencies responsible for managing resource development in this area require a comprehensive understanding of the environmental impacts of current and proposed future development. However, there is currently a lack of detailed information on the location, identity and vegetative state of human disturbances related to petroleum development in the region. This in turn hinders the capacity to adequately assess the effects of these disturbances on woodland caribou, and make informed regulatory decisions on future resource development. Current remote sensing tools have been shown to provide an effective foundation for mapping and characterizing linear disturbances, but have never been applied systematically in the Sahtu region.

The primary goal of this research is to develop remote sensing tools and protocols for mapping linear disturbance features in a northern boreal environment by (i) comparing the capacity of various remote sensing data sources to characterize linear disturbances, (ii) developing remote sensing protocols for mapping the occurrence and characterizing the attributes of linear disturbances that are suitable for use across large areas of boreal forest, and (iii) producing map layers that accurately portray the location and physical attributes of linear disturbances in the Sahtu.

UAV and LiDAR data will be compared in their ability to extract linear features using a least-cost path derived from Digital Elevation Models (DEMS) and Digital Surface Models (DSMS). Spectral metrics (i.e., NDVI) will be extracted from high-resolution Quickbird, mid-resolution SPOT and low-resolution Landsat to provide visual patterns to assist in an object-based classification and structural metrics (i.e.,

average height of vegetation) will be extracted from high-density airborne LiDAR data to assist in characterizing linear features. The results produced from each remote sensing dataset will be compared to determine which dataset provides the best foundation for mapping linear disturbance features in this northern boreal environment.

The approaches developed will enhance our capacity to map human disturbances in the Sahtu region, and support ongoing efforts to understand the environmental effects of resource extraction in Canada's north.

## **LIABILITIES AND FINANCIAL ASSURANCES - YEAR IN REVIEW AND FUTURE PREVIEW**

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The Liabilities and Financial Assurances Division is a new Division that has been established to manage the government's responsibilities for environmental liabilities and financial assurances inherited from the Government of Canada under the Devolution Agreement. The presentation will review the activities of the LFA Division in the past year and discuss the upcoming initiatives, including the development of Financial Assurance Guidelines. These Guidelines are intended to provide a framework for estimating closure and reclamation costs and determining appropriate forms of security for resource development projects in the NWT. These initiatives will be discussed within the broader framework of establishing locally driven policy development to provide environmental protection and strong economic growth.

## CONSTRUCTIVE INSIGHTS INTO NAVIGATING THE REGULATORY PROCESS AND EARNING SOCIAL LICENCE

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It is hard to imagine a more challenging place and time than the Yellowknife City Gold Project in early 2014 to apply for a Land Use Permit for mineral exploration. It was immediately prior to devolution of lands and regulatory responsibilities to the NWT. Multiple responsible departments were being restructured. Yellowknife City Gold Project straddles Commissioner's Lands (Territorial) and Crown Lands (Federal). It includes the Old Crestaurum mine site and 80 years of 100s of exploration workings – a hybrid of land pending discussions on sharing government responsibilities for clean up post devolution – and a road in need of repair whose ownership was unclear.

The environmental history of gold mining in the City cast a plume of anxiety over every discussion of revitalising the industry. Aboriginal memories were of exclusion and damaging the land and the scares of labour strife were painfully close to the surface. Like many projects, the Yellowknife City Gold Project is in Chief Drygeese Territory, an unsettled claim area, with over lapping settled claims and asserted interests. It is the first project in the NWT in which the community of greatest impact is a non-aboriginal community and public institutions such as the Department of Transportation and NWT Power Corporation have assets crossing the project.

The Yellowknife City Gold Project and its hundreds of miles of historic drilling and

harvesting trails and portages had become the play ground for the City's multiple community recreational groups and in hot demand by the recreational cabin community. These additional communities of interest had not previously been parties to permitting processes.

Yet with multiple letters of support and non-objection the Permit was granted in near record time.

TerraX Mineral's set the stage for navigating the regulatory process and earning its social licence by meeting with Yellowknife Dene First Nation before ever setting foot on the land package it purchased and by entering into projects to promote co-usage of safer and improved trails with recreational groups.

## INCREASING COMMUNITIES' UNDERSTANDING OF PROSPECTING: 2015 INTRODUCTION TO PROSPECTING COURSES

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Introduction to Prospecting courses were held in Yellowknife and the neighboring communities of Behchoko and Dettah. These two-day courses involved both classroom and field learning opportunities, and took place between September 26th to October 4th 2015.

The courses were organized by a working group with members from Government of the Northwest Territories departments of Industry, Tourism and Investment, and Education Culture and Employment, as well as the NWT Mine Training Society, the

NWT and Nunavut Chamber of Mines, Skills Canada, TerraX Mineral Inc., and the Tlicho Government. Additional sponsorship was provided by Aurora Geoscience. This presentation will discuss the 2015 Introduction to Prospecting courses': goals and objectives, out-reach efforts, pre-course planning and organization, course curriculum, outcomes, and attendance. We will also present the improvements made from the Introduction to Prospecting course that was offered last year in Yellowknife, and the lessons-learned that can be applied to future outreach programs.

## **EFFECTS OF FIRE AND DEVELOPMENT ON BATHURST CARIBOU WINTER RANGE HABITAT SELECTION**

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Barren-ground caribou are a migratory species and their ability to locate suitable resources on different seasonal ranges is important to their survival and reproductive success and coping with environmental variability. The winter range is important because it immediately precedes the calving period and represents a time when energetic costs of thermoregulation and foraging are high and body reserves required to maintain cow pregnancy are typically decreasing. For Bathurst caribou, the winter range has historically included a large area of boreal forest, which is subject to spatial and temporal variation of wild fire and human development disturbance. A new resource selection model for the Bathurst caribou winter range was developed with collared

cow data from 1996 to 2015 to assess factors important to caribou distribution on their winter range. These data were used to determine the relative importance of different vegetation communities, and the size, age and frequency of fire, different types of development, density dependence (herd size) and the segment of the Bathurst herd that remains on the barren-grounds during winter. This was accomplished by comparing locations used by caribou with a random sample of locations describing available habitat. Available habitat was defined as the area outside of individual home ranges but within the cumulative area used by all other collared caribou cows. We used a hierarchical approach of information theory to identify the most supported resource selection models representing different ecological hypotheses with variables supported by Traditional Knowledge in mixed-model logistic regression. Our study builds on work from two previous Bathurst caribou winter habitat selection studies and uses more recent techniques to determine indirect effects (zones of influence) to habitat quality associated with different development including active mines, exploration camps, power transmission lines, winter roads and communities. The results of this study will be informative to land use plans, caribou management and future environmental assessments.



## **PROXIMA DIAMONDS CORP.: EXPLORING FOR DIAMONDS IN THE FERTILE SLAVE CRATON**

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Proxima Diamonds Corp. is a private Canadian diamond exploration company exploring diamond targets in the heart of the diamond producing region of the Slave Geological Province. The company holds 17 target-rich properties that were selected based on a review of publicly available data, a proprietary kimberlite indicator mineral sample database and a wealth of experience exploring for diamonds in Canada's north.

Focused kimberlite indicator mineral (KIM) sampling conducted by Proxima in 2014 identified a potential source area on the Sancy Property, located near the northern boundary of the Ekati Diamond Mine. Follow-up ground geophysical surveys completed over the area in spring 2015 have returned compelling results. Ground gravity, total magnetic field and capacitively coupled resistivity surveys identified a large, new target approximately 300 m from the diamondiferous T-10 kimberlite pipe. On this and other Proxima properties, focused KIM till sampling is defining likely source areas which will be surveyed with ground geophysical methods this winter.

## **WATER AND HYDRAULIC FRACTURING: WHERE KNOWLEDGE CAN BEST SUPPORT DECISIONS IN CANADA**

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The rapid rise in the development of unconventional oil and shale gas reserves over the last decade has been accompanied by an explosion of discussion and debate on the topic. Central to the vast majority of conversations about hydraulic fracturing is the issue of water - its use, its management and protection and its ecological and socio-economic importance. What has been lacking is a clear and trusted articulation of the key questions facing decision makers, a prioritization of knowledge gaps tied directly to those decisions, and an assessment of how addressing them can lead to actionable solutions for government and industry.

In 2014, five projects - involving over 70 researchers from 18 universities across Canada, were funded by CWN to investigate where knowledge gaps are most centrally connected to our needs and questions involving water and hydraulic fracturing activities. Building on these five national research projects and drawing on other leading international work, CWN compiled a national overview report, which takes a high-level look at where the knowledge base is relative to the key questions being asked.

The report:

- frames and articulates the key questions that underpin decisions on hydraulic fracturing;

- presents and strategically organizes an updated state-of-the-knowledge within the context of the key questions; and,
- identifies the most relevant opportunity areas to address key questions.

The report found that the majority of the key questions underpinning decisions can be grouped within one of three decision contexts:

- deciding where and when hydraulic fracturing makes sense based on the overall benefits and costs;
- informing best practices and regulations with an understanding of the risks, and how to mitigate them; and
- achieving constructive and effective engagement to move discussion and decisions forward to achieve progress.

The key questions being asked within each of these decision contexts provides an accessible entry point and organizing framework for assessing what the overall knowledge base can offer. The outcome of the report's analysis is to identify practical opportunities to move the knowledge base forward to directly inform decisions.

Following the release of the national overview report, CWN launched a broad consultation process to identify which knowledge areas are both practical to advance and will address the most important questions facing decision makers. The two-stage consultation includes a national survey of decision makers, research providers, and other key influencers, followed by an in-person forum to identify shared national priorities as well as region-specific priorities. This process will ensure that results can be used to achieve success through broad collaboration across jurisdictions, while recognizing the significant differences in regulatory and

geographic contexts across the country.

Based on the outcome of the national assessment and forum, CWN will release a National Water and Hydraulic Fracturing Priorities Report on behalf of the individuals and organizations that provided input into the prioritization of knowledge gaps. The objective of the priorities report is to frame the work and decisions for government and industry to get the most value from their research investments as they address critical questions.

## **PRAIRIE CREEK MINE, NWT: UPDATE**

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The Prairie Creek Mine high grade base metal deposit located in the Mackenzie Mountains, 200km west of Fort Simpson in the Northwest Territories was fully permitted in 1982 and mine infrastructure was built, however, the mine never achieved production. Canadian Zinc has, through many years of exploration, continued to successfully expand the Pb, Zn, Ag, and Cu mineral resource to ensure a significant life of mine can be incorporated into mine economics.

Exploration drilling in early 2015 revealed that a previously-inferred 70m offset of the primary orebody, the Main Quartz Vein, is in fact a partially parallel vein with a sizeable and mineralized translation zone, termed the Stockwork Zone, occurring between the two. It is postulated that mineralization within this Stockwork zone occurred as a precursor to the faulting and movement of the Main Quartz Vein but that the actual stress event is similar for both.

## **DEVELOPMENTS IN THE LAW RELATED TO LAND AND WATER REGULATION IN THE MACKENZIE VALLEY, NWT**

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In April 2014, the 'Northwest Territories Lands and Resources Devolution Agreement' was implemented. The legislation giving effect to Devolution was accompanied by a series of changes to federal laws driven by Canada's Northern Regulatory Improvements Initiative including a series of amendments to the Mackenzie Valley Resource Management Act (MVRMA). Additional MVRMA amendments were set to come in to force in 2015 and 2016. This presentation will survey these changes and provide an overview of the new regulatory landscape. In addition, recent developments and northern cases on s.35 consultation will be summarized and discussed.

## **PLANNING FOR RESOURCE REGIONS IN NORTHERN CANADA**

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Increasingly, regional planning in northern Canada must address the dynamics particular to resource regions. Resource regions are characterized by: Numerous resource operations within a defined regional geography/landform, which is often remote; Significant infrastructure investment and development is required to support resource operations and communities; Workers are typically accommodated in work camps, following fly in/fly out lifestyles which are socially destructive;

Limited support for pre-existing local economies and livelihoods, particularly Aboriginal communities; Significant influx by others hoping to benefit from resource spin-offs; Potential for significant environmental degradation. A multi-stakeholder approach to planning for resource regions can be the most effective way to establish a comprehensive framework for regional development. rePlan's recent regional planning processes – one in northern Alberta and the other in northern Manitoba – address the challenges inherent in managing the long-term sustainability of resource regions.

## **SLAVE PROVINCE SURFICIAL MATERIALS AND PERMAFROST STUDY OVERVIEW - REVITALIZING MULTI-COMMODITY MINERAL EXPLORATION AND FACILITATING SUSTAINABLE DEVELOPMENT IN A KEY ECONOMIC REGION**

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In 2014 the Northwest Territories Geological Survey (NTGS) initiated the Slave Province Surficial Geology and Permafrost Study (SPSMPS) in NTS sheets 76C and 76D. The SPSMPS is a two year collaborative government –industry – academic research project funded through the Strategic Investments in Northern Economic Development program of the Canadian Northern Economic Development Agency. The main objectives of the SPSMPS are to:

- Produce a 3D database of indicator minerals to identify areas of high mineral

potential;

- Advance our understanding of glacial history to aid in mineral exploration;
- Update surficial maps in targeted areas;
- Study the impact of climate change on permafrost and terrain sensitivity to inform potential infrastructure development.

In order to accomplish these objectives, 235 boreholes were drilled to sample a wide variety of glacial sediment, over 1250 samples were collected, and approximately 240 thermistors were installed at 41 LIDAR surveyed sites. In addition, over 1500 km<sup>2</sup> of field mapping and approximately 150 line km of ground geophysics were carried out. Large proprietary indicator mineral and remote sensing datasets along with logistical support were generously provided by our industry partners.

Our industry partners include the Canadian Mining Institute Research Organization (CAMIRO), Dominion Diamond Ekati Corp, Diavik Diamonds Mines Inc., North Arrow Minerals Inc., Peregrine Exploration Ltd., Artic Star Exploration Corp., New Nadina Explorations Limited, and TNT Mineral Science. Academic Partners include Dr. Martin Ross (University of Waterloo), Dr. Brent Ward (Simon Fraser University), Dr. Stephan Gruber (Carleton University) Dr. Don Cummings (Carleton University) and the Dr. Peter Winterburn (University of British Columbia). This work was carried out by or with support from Aurora Geosciences Ltd.

The SPSMPS also included numerous targeted studies such as:

- A 3D indicator mineral entrainment study to show how indicators get from source to surface;

- A 3D GPR survey of the Exeter Lake Esker to better understand esker formation, material transport distances and ideal sampling mediums for indicator minerals;
- LIDAR and drill assisted surficial mapping of enigmatic landforms associated with glacial outwash corridors in the region;
- Drill assisted surficial mapping to determine detailed local ice flow direction and glacial history associated with sourced and un-sourced indicator mineral trains in areas with complex and poorly understood surficial geology;
- A network of thermistors was established to determine variability in ground temperatures and monitor the impact of climate change on permafrost in a wide variety of terrain types;
- A comparative surficial geochemistry and soil gas study over a buried kimberlite;
- Developing and refining a reliable methodology for rapidly identifying indicator minerals below 500 µm in size using hyperspectral imaging;
- Developing a snowmobile towed ground geophysical method for rapidly determining overburden depth to bedrock.

## SLAVE PROVINCE SURFICIAL MATERIALS AND PERMAFROST STUDY CONCLUDING PRESENTATION

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- Produce a 3D database of indicator minerals to identify areas of high mineral potential;
- Advance our understanding of glacial history to aid in mineral exploration;
- Update surficial maps in targeted areas;
- Study the impact of climate change on permafrost and terrain sensitivity to inform potential infrastructure development. This presentation will summarize the preliminary results of this study and will present some potential ideas for future work in the region.

## 2015 EXPLORATION OVERVIEW

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The Northwest Territories (NWT), which has led Canada in diamond and tungsten production, will change back to a single commodity producer. Cantung will shut down and move to a care and maintenance status as North American Tungsten moves through a creditor protection process. While diamonds did not suffer as great a depression in the commodity prices as tungsten and the base metals, the poor rough diamond sales prices did slow the diamond staking resurgence that was seen last year.

Production from the Ekati and Diavik diamond mines met expectations with Ekati producing 1.7 million carats during the first six months and Diavik producing 4.9 million carats by the end of September. Positive results from Ekati also included the prefeasibility work on the Sable kimberlite

and the proposed time frame for development of the Jay pipe with the potential for construction in the latter half of 2016. NWT diamond production figures for the first six months of the year were also augmented by .68 million carats produced from Snap Lake.

Despite the economic climate, some positive notes were generated by the De Beers/Mountain Province construction updates on the advancement of Gahcho Kué towards production status and the results of bulk sampling from Kennady Diamonds' property. A highlight in metals exploration is the continuing advancement of Canadian Zinc's Prairie Creek Zinc-Lead project to the development stage with the initiation of underground rehabilitation work. Despite a poor financial market for gold exploration, two projects had continued to drill including Nighthawk's Colomac Gold Project and TerraX's Yellowknife City Gold project.

Less fortunate are the NICO and Nechalacho development projects which have been put on hold, lacking funds for construction and challenges over processing plants; while Fortune Minerals and Avalon Rare Metals focus on southern projects. This is also the case for advanced projects such as the Ormsby and Courageous Lake gold projects.

Natural Resources Canada's March estimates of \$43.5 million in intended expenditures on exploration and deposit appraisals for the NWT largely demonstrate a substantial drop in expenditures. The announced spending for this year had not reached half of the \$95.8 million predicted for 2014. Of the current estimate, the bulk of the expenditures were for major capital expenditures at advanced diamond projects (NRCAN, February 2015). Grassroots exploration spending continues to languish.



By October, 17 new claims totaling 6,956 hectares had been staked in the Northwest Territories. This marks a notable low level when compared to 2014 levels (411 new claims totaling 433,950 hectares). In contrast to staking, the statistic for dropped claims have risen to 179 claims covering 139,943 ha and 4 mineral leases covering an additional 2,122 ha. The depressed diamond prices were part of the reduced interest in land acquisitions this year. Since 2005, the amount of land covered by mineral tenure has fallen from 19.8% to the current level of 2%. Daily updates can be viewed on-line through the Government of Northwest Territories' (GNWT) Mineral Tenure Map Viewer ([www.geomatics.gov.nt.ca](http://www.geomatics.gov.nt.ca)).

## **GSC BEDROCK MAPPING AND STRATIGRAPHIC STUDIES OF THE COLVILLE HILLS, NORTHWEST TERRITORIES**

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As a contribution to the Mackenzie Project of the Geological Survey of Canada's Geomapping for Energy and Minerals Program, bedrock mapping and stratigraphic studies of the Colville Hills petroleum exploration area was undertaken in July and August of 2015. Outcrops were examined for stratigraphic and structural relationships within NTS map areas 96K, 96L, 96M, and 96N. Known petroleum seeps within the area were also visited to examine their geological setting and collect samples. The aim of this work was to improve existing geological maps of the area, clarify the stratigraphic history of the region, refine the structural relationships in conjunction with available public-domain reflection-seismic

data, and relate these features to the petroleum system.

To improve upon reconnaissance-scale mapping by the Geological Survey of Canada in 1968, some effort was made to subdivide the Franklin Mountain and Mount Kindle formations, address lithologic variations in the Bear Rock interval – including identifying strata possibly belonging to the Delorme Group – and resolve the Cretaceous succession. It is hoped that samples collected for biostratigraphy will be able to confirm initial impressions from field observations. These initial impressions suggest that each of these unconformity bounded intervals is variably preserved across the study area, providing indications of different periods of deposition versus uplift and erosion related in part to the Keele Arch.

Published maps based on the 1968 reconnaissance work interpreted the region's prominent topographic ridges to be underlain by elongate anticlines. Recent reflection-seismic data interpretations suggest the presence of thrust faults and/or steeper reverse faults associated with the major structures and 2015 field work has locally confirmed these relationships at surface. Efforts to subdivide stratigraphic units have also revealed additional faults in the southern part of the study area, at the northern edge of the Franklin Mountains. Tilting of Cretaceous strata on the flanks of major structures suggests that the formation of surface structures in the Colville Hills was later than the Early Cretaceous, likely as part of the development of the adjacent Franklin Mountains and Mackenzie Mountains. The Colville Hills differ, however, in that the orientation of the major structures is more variable and generally at high-angle to Cordilleran structural trends. Based on reflection-seismic evidence, this

may be the result of reactivation of older normal or reverse faults in the subsurface.

Petroleum seeps visited in 2015 were noted to occur in close proximity to interpreted steeply-dipping faults. Since the Devonian source-rock, the Canol Formation, is known to be absent in the Colville Hills, it is suspected that the petroleum may have migrated to surface from Cambrian Mount Clark or Mount Cap strata along the mapped faults. Samples collected in 2015 will be geochemically fingerprinted to compare with known regional petroleum sources to test this hypothesis.

**ACQUIRING CRUSTAL  
DILUTION DATA AND  
KIMBERLITE  
COMPOSITIONAL  
INFORMATION FROM DRILL  
CORE USING SWIR  
HYPERSPETRAL IMAGERY  
FROM THE TANGO  
EXTENSION KIMBERLITE**

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Short-wave infrared (SWIR, 1.90-2.36  $\mu\text{m}$ ) hyperspectral imagery collected from 171 meters of drill core from the diamondiferous Tango Extension kimberlite using a high spatial resolution imaging system (pixel size: 1.43 x 1.43  $\mu\text{m}$ ) was analyzed to create compositional maps that show the distribution of different crustal (dilution) components and different kimberlite types along the drill core. Three types of crustal

dilution components were identified in the compositional maps: carbonate, a carbonate-mudstone mixture, and mudstone. Five spectrally distinct types of kimberlite were identified, which differ mainly in their level of hydration and the amount of crustal micro-dilution they contain.

Accompanying the compositional maps are depth profiles that provide quantitative abundance information for each compositional component (dilution and kimberlite). These profiles show the abundance of macro-dilution relative to kimberlite and the spatial distribution of the different kimberlite types. Using depth profiles, compositional boundaries along the length of the drill core were identified and compared to the unit boundaries from the visual lithological log. The boundaries identified using the hyperspectral imagery correlate well with the boundaries recorded during visual logging.

This study demonstrates that hyperspectral imagery is well suited to the task of mapping the distribution of spectrally distinct kimberlite types, and quantifying kimberlite micro- and macro-dilution by crustal rocks.

**NORTHWEST TERRITORIES  
GEOLOGICAL SURVEY (NTGS)  
PETROLEUM GROUP  
SUMMARY OF ACTIVITIES:  
DECEMBER 2014 TO  
NOVEMBER 2015**

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The NTGS Petroleum Group advances petroleum geoscience knowledge of the Northwest Territories by conducting field and subsurface research studies and provides related technical advice to industry, communities and government. The Petroleum Group's current active project areas include the Mackenzie Plain, also known as the Central Mackenzie Valley (CMV) and the Liard Basin. The Petroleum Group initiated three new major projects in 2014-15. These included two unconventional petroleum resource assessment studies initiated with the National Energy Board (NEB) and a Northwest Territories Petroleum Atlas Scoping Project study. The first study evaluated the resource potential associated the Devonian age Bluefish and Canol shale in the CMV and was completed in May 2015. A similar study was undertaken with the Yukon and BC geological surveys and the NEB to assess the resource potential of the Exshaw Formation in the Liard Basin. This study will be completed in January 2015.

**BLUEFISH AND CANOL SHALE  
MAPPING PROJECT –  
MACKENZIE PLAIN,  
NORTHWEST TERRITORIES**

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The Northwest Territories Geological Survey (NTGS) “Regional Geoscience Studies & Petroleum Potential of Mackenzie Plain Area, Central Northwest Territories” project spanned the 2009 to 2014 time period. The primary goal of this project was to characterize the hydrocarbon potential of the Devonian age Bluefish and Canol shale. Field and subsurface studies results and data sets were reported at petroleum conferences and published annually in NTGS Open Files and Reports. The Bluefish and Canol shale are kerogen rich siliceous source rocks with low clay content and are thermally mature for oil throughout most of the study area. This study helped propel the Bluefish Member of the Hare Indian Formation (Fm.) and Canol Fm. shale into an emerging unconventional shale oil play. Industry acquired fourteen exploration licenses for work bid commitments of close to 630 million dollars and drilled five vertical and two horizontal wells to further evaluate the play over the 2011 to 2014 time frame.

In June of 2014, the NTGS Petroleum Group determined there were adequate data sets available to initiate an unconventional hydrocarbon resource assessment of the Bluefish and Canol oil shale in the Mackenzie Plain area of the Northwest Territories. NTGS and the National Energy Board (NEB) entered into a research agreement in the fall of 2014 and the resource assessment project was initiated. In January 2015, the NTGS Petroleum Group provided the NEB with detailed geological



mapping of Canol and Bluefish shale data sets for resource assessment modelling using probabilistic methods they recently developed to assess the unconventional oil resources in the Montney Fm. of British Columbia and the Bakken Fm. of Saskatchewan. This presentation will review the results of the Canol and Bluefish shale mapping project.

## **OFFICE OF THE REGULATOR OF OIL AND GAS OPERATIONS (OROGO) - UPDATE**

**JAMES, F.**

OFFICE OF THE REGULATOR OF OIL AND GAS  
OPERATIONS

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The Office of the Regulator of Oil and Gas Operations (OROGO) assumed regulatory responsibility for oil and gas operations in the NWT onshore outside of the Inuvialuit Settlement Region and federal areas on April 1, 2014. While carrying out its statutory responsibilities, OROGO strives to:

- Be as transparent and open as possible about its work;
- Build effective working relationships with other regulators, GNWT agencies and Aboriginal governments; and
- Educate stakeholders about its role and the role of the GNWT Regulator.

The presentation will provide an update on OROGO's efforts to meet these objectives while maintaining its readiness for a return of exploratory activity.

## **NWT MINING INDUSTRY VALUE CHAIN**

**GAUTHIER, F., and PELLETIER, P.**

LES CONSULTANTS FRÉDÉRIC GAUTHIER ET  
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Mineral wealth in the Northwest Territories represents great potential in attracting investments to the region, and, by the same token, economic development. Along with the adoption of its NWT Investment Attraction Strategy, the Conseil de développement économique des Territoires du Nord-Ouest (ÉTNO) commissioned outside consultants to conduct a study on the NWT mining industry value chain in order to clarify the roles, relationships and interactions of this activity sector. The study conducted in March 2015 presents the synergies among the various stakeholders and sheds light on development opportunities in the Northwest Territories.

Methodology: The consultants conducted in-depth documentary research and collected data from 142 NWT businesses working in the mining sector. In order to grasp stakeholders' thoughts on the sector's challenges and opportunities, the consultants also communicated with 21 representative entities of stakeholders involved in the Northwest Territories' mining industry value chain. Based on the information collected, a matrix of the Northwest Territories' mining industry value chain was designed to illustrate the main activities covered by the stakeholders involved in the value chain, the goal being to identify development opportunities.

## MEASURING THE EFFICIENCY OF GREASE RECOVERY AT DIFFERING FEED RATES AND SCRAPE INTERVALS

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As a secondary method of diamond recovery, a series of grease tables are currently employed at the Diavik Diamond Mines (DDMI) process plants. They exploit the oleophilic properties of diamond, whereby diamonds will adhere quite strongly to grease. At DDMI, this grease is manually applied by an operator in a thin layer on a multi-layered table, then scraped off, melted, and sorted for diamonds at defined intervals of time. Measuring the recovery performance of grease has traditionally been difficult due to an inability to accurately control input feed grade. By employing two different experimental protocols, the performance of the tables was measured at varying feed rates and intervals between grease scrapes. In the first case, the tables were bisected, with one side being scraped and analyzed every 4 hours and the other scraped and analyzed every 6 hours for a variety of material flow rates. In the second case, the each tier of the table was scraped simultaneously, but analyzed separately and evaluated for diamond recovery as a percentage of total carats recovered. The result of this investigation is an indication of the performance degradation of the recovery efficiency of grease at increasing scrape time intervals.

## THE SLAVE PROVINCE SURFICIAL MATERIALS AND PERMAFROST STUDY: RATIONALE AND FIRST RESULTS OF THE PERMAFROST PART OF THE PROJECT

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The Slave Geological Province is one of the foci of resource extraction in the Canadian North. Its tundra areas form a large and diverse landscape in which comparably few systematic permafrost observations exist. As the region contains layers of icy till, it is susceptible to modification upon thaw. The strong consequences that permafrost thawing can have on infrastructure and the natural environment motivate baseline investigations.

This project contributes to better understanding the ground thermal regime and ground ice content, as well as geochemical properties of permafrost. Specifically, we investigate how differing parts of the landscape differ in ground temperature dynamics and subsurface ice content. A network is put into place to track changes in ground thermal regime and ice content over time in more than 40 locations. This type of data provides infrastructure planners, industry and regulators an advantage in designing projects, anticipating impacts and planning mitigation. Additionally, measurements in boreholes are complimented with distributed logging of near-surface ground-temperature as well as surface observations suitable for

parameterizing land-surface models. This will allow using the data collected for advancing scientific understanding of atmosphere-permafrost interactions and for evaluating the quality of global or continental scale climate models in simulating permafrost dynamics.

This presentation provides a synopsis of the project rationale and summarizes the work accomplished in 2015 with respect to measurements made and instruments deployed. First results will be highlighted, some of which are shown in more detail in other presentations at this conference. An outlook on future work and benefits will finish the presentation.

## GLACIAL HISTORY AND LANDFORM GENESIS IN THE LAC DE GRAS AREA AND IMPLICATIONS FOR KIMBERLITE DRIFT PROSPECTING

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During the last glaciation, bedrock was eroded, transported and deposited by the Laurentide Ice Sheet across much of Canada. The complex ice and meltwater processes that resulted in sediment deposition are not completely understood. In the central Slave Craton, Northwest Territories, glacial sediments overly many diamond-bearing kimberlites. Diamond deposits in the Lac de Gras area were discovered in the early 1990s by drift prospecting. To better interpret drift

prospecting datasets a more thorough understanding of the detailed glacial history of the area is required.

We spent six weeks in the Lac de Gras area in summer 2015. Field mapping was complimented by a number of other techniques to elucidate the glacial history of the area. Enigmatic landforms were examined in detail and pits were dug to examine their sedimentology. Samples of matrix material were collected to compare grain size distribution between different sediment types. Pebble counts were done to consider sediment provenance. We also collected ground-penetrating radar profiles to look for stratified sediments within enigmatic mounds. High-resolution orthophotos and a one metre LiDAR digital elevation model of the area, obtained by Dominion Diamond Ekati Corporation, have also been used to investigate landform genesis and the glacial history of the area.

In the Lac de Gras area many meltwater corridors can be identified in the high-resolution imagery. These corridors are typically 300-1500 m wide and form dendritic networks. Between the corridors, sandy till of varying thickness overlies bedrock. Within corridors, glaciofluvial landforms and scoured bedrock are common. Also associated with corridors are many mounds of enigmatic origin. These mounds commonly occur in groups and are typically 20-100 m wide and rise 5-15 m above the surrounding area. They are usually composed of an unstratified to poorly-stratified sandy diamicton containing no clay and minor silt. Matrix grain size distribution and pebble lithology results from some mounds are similar to those of nearby regional till. However, patches of well-stratified sediments, exhibiting laminated silts as well as climbing ripples in sand, do exist on parts of some mounds.

GPR data suggests that these patches are discontinuous, and that the majority of mounds are composed largely of sandy diamicton. Variation in the sedimentology of the mounds does not appear to be related to variations in mound morphology.

It is likely that the majority of the glaciofluvial sediments in the Lac de Gras area were deposited during the final stages of ice retreat across the area when meltwater volumes were high. We suggest that the corridors were formed by subglacial meltwater flow. This is because glaciofluvial deposition almost exclusively occurs within corridors, very little till is found within corridors and the corridors have an undulating elevation profile in the direction of ice flow. Water must have played a role in the deposition of the well-stratified patches of sediment found on some mounds, however, the mounds may not be solely the product of subglacial meltwater flow. A thorough understanding of sediment transport and depositional processes is critical if kimberlite indicator mineral data is to be accurately interpreted.

## **SUCCESSSES AND CHALLENGES ENCOUNTERED IN DEFINING NATURAL VARIABILITY FOR NORTHERN AQUATIC SYSTEMS**

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Characterizing natural variability in aquatic systems is necessary for differentiating anthropogenic influence from natural changes. Regulatory boards in the Northwest Territories are clear that monitoring programs are to be developed such that they provide a solid foundation for detecting change, assessing impact, and implementing adaptive management. The benefits of adequately characterizing natural variability are clear and widely accepted among stakeholders; however, the approach to defining this is widely variable. Some variation in approach may be warranted, depending on data type and availability. The presentation will outline successes and challenges encountered in defining natural variability within the northern regulatory framework. Discussion will be related to consistent data collection, filling data gaps, case studies, and recommendations for on-going collaboration. Participants will be encouraged to provide input and perspective from their work in furtherance of this topic.

## **GEOLOGY, STRUCTURE AND ALTERATION OF THE MAZENOD LAKE REGION, GREAT BEAR MAGMATIC ZONE, NWT**

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The ~70 km<sup>2</sup> Mazenod Lake region is located in the southern Great Bear Magmatic Zone (GBMZ) between the NICO (gold-cobalt-bismuth-copper) and Sue-Dianne (copper-gold-silver) iron oxide copper-gold (IOCG) deposits. Detailed field mapping and sampling were completed during the summer of 2013, and have now been compiled and augmented with a structural lineament analysis based on satellite imagery, geology and geophysics. The Mazenod region comprises a c. 1870 - 1.866 Ga suite of calc-alkaline rocks that range in composition from basaltic andesite to rhyodacite ignimbrite sheets, volcanoclastic rocks, associated high-level intrusions, a metasedimentary suite, and marginal intermediate to felsic batholiths. Structural analysis reveals several stages including pre- and syn-volcanic deformations to post volcanic disruption. Complex and regionally extensive hydrothermal alteration affects the entire suite of rocks within the region. Noted effects include extensive sodic, potassic, iron, and silica metasomatism, with significant areas of calcium, boron and sulphide alteration. Mineralization identified to date includes skarn, disseminated sulphides and minor pitchblende with copper being the most commonly observed metal of interest. The Mazenod region is characterized by several overlapping hydrothermal cells with varying styles of mineralization and alteration that are consistent with IOCG type systems. Parts of the system are most similar to that observed around Sue-Dianne, while other areas and

characteristics share similarities to parts of the Echo Bay and Conjuror Bay districts of the northern GBMZ.

## **ASSESSING MYCORRHIZAL SPORE DENSITY AND INOCULUM POTENTIAL OF SOILS OBTAINED FROM STEEVES LAKE SHORELINE: A REMEDIATION SITE AT THE COLOMAC MINE, NWT**

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The Colomac mine, located 220 km north of Yellowknife, was an open pit gold mine active throughout the 1990s. In 1999 Aboriginal Affairs and Northern Development Canada began closure and reclamation efforts at Colomac. Heavily contaminated near-shore sediments and the continuing presence of free phase diesel in the adjacent bedrock required remedial action along the shoreline of Steeves Lake. A new shoreline was constructed to cap the sediments and act as buffer to diesel migration into the Lake. The construction of the shoreline was completed and revegetation efforts were initiated in 2010. Ten thousand square meters of new riparian area were added alongside 750 m of the original shoreline. The design of the shoreline included an infill area extending out from the original shoreline contained within an outer armoured wall, as well as a trench in the armoured wall lined with landscape fabric and peat/sand infill. The



peat/sand infill material was obtained onsite. After infilling, the area was revegetated using local transplants and native seed mix. The purpose of this study was to quantify arbuscular mycorrhizal fungal (AMF) propagules in soils along Steeves Lake shoreline. AMF are soil dwelling, endophytic fungi that form symbiotic associations with vascular plants, exchanging nutrients for carbohydrates and have been shown to play an important role in plant survival in revegetation efforts. In order to determine if AMF were present, fungal propagules were isolated and bioassays conducted to measure propagule infectivity. *Phalaris arundinaceae* and *Epilobium angustifolium* seedlings were transplanted into soils from the site and grown under growth room conditions for a 4-week (*P. arundinacea*) or 6-week (*E. angustifolium*) period. Plants were then harvested and colonization assessed using standard procedures. Abiotic factors such as soil nutrient levels (K, P), distance of the samples from historic spills, and soil moisture were also considered. AMF propagules have been confirmed in all soil samples with spore densities ranging from 2 to 338 spores per gram of dry soil. In the colonized roots of both trap plants, hyphae, arbuscules and vesicles were observed, and all plants were colonized by AMF, dark septate endophytes, or both. In *P. arundinaceae* AMF colonization ranged from 1 to 78%, and 5 to 98% in *E. angustifolium*. Colonization levels were consistent throughout the area sampled.

## CONSTRAINING HYDROTHERMAL EVENTS RESPONSIBLE FOR REGIONAL POLYMETALLIC VEIN MINERALIZATION IN THE SOUTHERN SLAVE PROVINCES AND LINKS TO DEPOSITS IN THE GREAT BEAR LAKE MAGMATIC ZONE

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Small polymetallic (U-As-Ni-Co-Cu-Ag-Bi-Sb) hydrothermal vein systems are dispersed throughout the Southern Slave province (e.g., Copper Pass, Blanchet Island) and have similar paragenetic characteristics to deposits at Great Bear Lake (Eldorado-Echo Bay, Contact Lake, Terra-Norex, Silverbear, Normin) but are very low in grade and tonnage at their surface expression, and lacked productive U and Ag ore stages.

Current studies of these deposits at Saint Mary's University are focusing on the systematic application of a variety of microanalytical techniques to aid in the development of exploration criteria for polymetallic vein systems and revise the current model for this deposit style, specifically with respect to metal sources, metal precipitation mechanisms, and timing of metal precipitation, and the reasons for variability in metal tenor on a regional scale. In one study, we utilized petrographic and thermometric (CL, SEM, fluid inclusion microthermometry) and isotopic methods (SIMS, LA-ICPMS) to identify thermal, salinity and metal concentration gradients in



these hydrothermal systems. In another study, we are re-examining historic gamma surveys for deposit-characteristic U/Th ratios as proxies for basinal metalliferous fluid migration to delineate areas likely to contain these deposits.

The integrated results of several studies will be examined, highlighting (i) major compositional changes to metal-carrying fluids resulting from suspected isothermal mixing of very different fluid reservoirs, as the driving mechanism for metal deposition; (ii) the critical role of organics in transporting and precipitating uranium and other metals; and (iii) the regional resetting of U-Pb systematics, leading to erroneously young ages for mineralization, a result consistent with other recent attempts at resolving the age of similar polymetallic vein systems in the Great Bear Lake magmatic zone.

## **AN INTRODUCTION TO THE NWT ENVIRONMENTAL STUDIES RESEARCH FUND**

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The Northwest Territories Environmental Studies Research Funds (ESRF) is a research program which supports environmental and social studies to inform decision-making related to oil and gas exploration and development on lands within the NWT. The NWT ESRF program replaces the federal ESRF established in 1987 and will be a collaborative effort between the GNWT, industry and the public. Funding for the ESRF will be collected through levies paid by all interest holders of lands in the Northwest Territories. The ESRF is directed by a five member Management Board which has representation from the GNWT (2), the oil

and gas industry (2), and the general public (1).

This presentation will serve as an introduction to the NWT Environmental Studies Research Fund, its mandate, and its progress and achievements to date.

## **IMPROVING THE UTILITY OF ECLOGITIC GARNET IN DIAMOND-EXPLORATION – EXAMPLES FROM LAC DE GRAS AND WORLDWIDE LOCALITIES**

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In diamond exploration, the use of compositional data to identify diamond-related peridotitic xenocrysts has long been a widely used and powerful tool. In contrast, the application of similar methods to eclogitic garnet chemistry remains a challenge. The inability to unequivocally classify certain “eclogitic” garnet compositions as either mantle- or crust-derived implies that a high abundance of lower-crustal garnets will increase diamond-exploration expenditures by introducing a number of “false positives”. Revising existing classification schemes (e.g., Schulze, 2003) to reduce the abundance of “false positives” may, however, increase the number of “false negatives” through the misclassification of mantle-derived garnets as crustal.

This study presents new geochemical and

petrographical data for garnet and clinopyroxene from 724 kimberlite-hosted, crust- and mantle-derived xenoliths from localities worldwide, with a focus on samples whose lithology is constrained petrographically, rather than single mineral grains from concentrate. Mantle samples are primarily eclogitic and pyroxenitic, as constrained by mineral assemblage and garnet and clinopyroxene mineral chemistry, while crustal samples are dominantly plagioclase-bearing garnet-granulites.

For those localities where an established geothermal gradient is available from literature resources, garnet-clinopyroxene pairs are employed in the estimation of pressure-temperature conditions of equilibration through the iterative coupling of the Krogh (1988) geothermometer and the relevant geothermal gradient. Our preliminary results suggest that closure temperatures for Fe-Mg exchange exceed the temperatures of residence of many lower-crustal samples, as geotherm-based calculated pressures of equilibration exceed the apparent stability of plagioclase (see Green and Ringwood, 1972). Comparison of equilibration pressures with sodium contents in garnet for mantle-derived samples (the diamond-facies criterion of Gurney, 1984) shows a positive correlation at localities for which an adequate range of pressures is observed (e.g., the Diavik mine). Other populations, such as mantle eclogitic garnets from Roberts Victor, plot at a much more restricted range of pressures and hence fail to demonstrate this correlation; instead, these samples may reflect the influence of a broader range of bulk-compositions, providing varying amounts of sodium to their constituent garnets.

The results presented here demonstrate clearly that garnets from mantle- and crust-derived samples show significant overlap in

geochemical character, for example in garnet Ca# vs. Mg# space (discrimination diagram of Schulze, 2003), where approximately 66% of our crust-derived garnet analyses plot in the “mantle” field. This percentage varies among locations. A selection of particularly high-Mg#, low-Ca# garnets derived from crustal, plagioclase-bearing lithologies in this study highlights the potential for crust-mantle confusion, as these garnets have Mg# in-excess of many mantle-derived eclogitic/pyroxenitic garnets. As a consequence, Fe-Mg-Ca-based classifications alone cannot reliably discriminate mantle and crustal garnets.

The next step in this project will be to obtain trace element data for the entire sample suite. This will allow us to test the Li-geobarometer of Hanrahan et al. (2009) for eclogites and to search for trace element signatures that can be used as robust indicators of a diamond-facies origin of eclogitic garnets. Trace element data will also be employed in the refinement of the crust/mantle division discussed above.

## **EARLY CAMBRIAN CARBONATE RAMP SIGNATURES IN THE MOUNT CLARK FORMATION, DODO CANYON, NT**

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

The Mount Clark Formation has been studied by the Geological Survey of Canada and Northwest Territories Geological Survey in regional and primary investigation programs. However from a general viewpoint, the Mount Clark Formation's depositional affinities are poorly understood with fluvial to shallow marine environments proposed within an existing lithostratigraphic scheme. This new research aims to better identify depositional environments using detailed ichnological and sedimentological investigations.

Within the mixed Carbonate-Clastic Mount Clark succession present at Dodo Canyon carbonate peritidal facies associations have been identified in the upper portion of the section near the Mount Cap boundary. Newly described observations include: 1) unbioturbated ?microbial dolomitic laminites ; 2) impoverished trace-fossil suites, 3) unbioturbated micritic deposits, 4) massive penecontemporaneous soft-sediment deformation structures, and 5)

skeletal packstones and wackestones comprised of brachiopod and sponge spicules. These newly identified observations and interpretations provide evidence of physio-chemical stresses and an energetic carbonate environment: 1) we associate the low-diversity and locally impoverished trace fossil suite to an increase of marine salinities, potentially related to supratidal and intertidal conditions; 2) burrowed wackestone and packstone beds are taken to represent energetic mid-ramp conditions; and 3) abundant soft-sediment deformation features can be associated with synsedimentary collapse events perhaps driven by active tectonics. At Dodo Canyon we interpret the presence warm water carbonate ramp with evaporitic intertidal to supratidal conditions.

## **TO BE OR NOT TO BE CONSERVATIVE – A WATER QUALITY MODELLING CASE STUDY IN THE NORTHWEST TERRITORIES**

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Dominion Diamond Ekati Corporation submitted a Developer's Assessment Report (DAR) for the Jay Project (the Project) in November 2014. A component of the DAR was to evaluate the impact of Project discharges on surface water quality in Lac du Sauvage and Lac de Gras during operations, closure, and post-closure. A water quality model was developed to predict Project effluent water quality, and the water quality in the receiving environment as a consequence of the Project

effluent discharge, so as to assess the influence of the effluent on downstream receptors. The model relied on conservative assumptions for each of the inputs to ensure future operational discharge concentrations would not be underestimated.

Diamonds will be mined from the Jay Pit, which will be developed within a diked and dewatered portion of Lac du Sauvage. Open pit mining at the Project has the potential to result in saline groundwater upwelling into the Jay Pit. To minimize the total load of saline water requiring discharge over the life of the mine, and to minimize the risk of adverse effects to the receiving environment, water reporting to the Jay Pit will be pumped to the bottom of the mined out Misery Pit during operations. This process maintains a surface water quality in Misery Pit, which can be subsequently discharged to Lac du Sauvage after the Misery Pit design storage elevation is reached, and maintained until the end of mine operations.

The upper 50 metres of saline mine water stored in the Misery Pit will be pumped to the bottom of the mined out Jay Pit at closure. The saline water will be capped with freshwater pumped from Lac du Sauvage to produce meromictic conditions in the Jay Pit, permanently isolating the saline water from interacting with freshwater in the overlying Lac du Sauvage. Similarly, the 50 metre freeboard in Misery Pit will be capped with freshwater from Lac de Gras or Lac du Sauvage. The stability of meromixis in both pits is dependent primarily on the density difference between water stored in the pit lake mixolimnions and monimolimnions. Therefore, increases in conservatism in operational effluent water quality predictions can reduce the conservatism in post-closure pit lake stability predictions since increases in salinity concentrations will result in an

increased post-closure density gradient in the Jay Pit, strengthening the pit stability.

This presentation provides a case study of the comprehensive water quality modelling that was completed as part of the Project DAR and subsequent model iterations that were completed to address stakeholder comments and concerns. Several water quality scenarios were evaluated to address uncertainty in the DAR predictions and to include appropriate conservatism into all aspects of the surface water quality assessment to ensure the Project is designed and operated in an environmentally protective manner. The need for a multi-faceted modelling approach for evaluating surface water quality impacts from northern mines will also be discussed.

## **REVEGETATING COLOMAC MINE, NT: FIVE YEARS LATER - UPDATE ON THE BIOENGINEERING TECHNIQUES FOR REVEGETATION OF RIPARIAN AREAS AT THE COLOMAC MINE, NT**

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Factors such as nutrient poor soils, harsh climate, remote locations, and high costs make revegetating disturbed areas in northern environments a challenge. We present a case study where innovative bioengineering and project planning techniques were employed to revegetate and

remediate two riparian areas at Colomac Mine, an abandoned gold mine 220 km north of Yellowknife, NT. The revegetation plan focused on establishing pioneer species and facilitating natural recovery and succession. A “rough and loose” technique was used to allow the soil to capture and retain moisture, trap windborne seed, promote easy root penetration and prevent erosion. Harvesting and planting of local willow cuttings, alder seeds, and sedge plugs ensured that the vegetation at these sites was adapted to local climate and soils. Multi-year monitoring was initiated which included vegetation counts and photographic documentation. Results have shown success rates of 60-100% plant survival on the majority of areas where bioengineering techniques were used. In contrast, poor revegetation success rates of 8 to 33% plant survival were experienced in areas where techniques were either used incorrectly or implemented too late in the season. The bioengineering techniques implemented at Colomac Mine provided a successful, cost effective, and local approach to revegetation in a northern environment.

## **RAYROCK (Kwetłı́zaà) WATERSHED TOUR**

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The Rayrock (Kwetłı́zaà) Mine Site is a decommissioned uranium mine located in one of the ‘donut holes’; that is, Crown Land located within Tłı́chų Lands boundaries. It operated between 1957 and 1959. Eighty-thousand tonnes of ore were milled at the mine, creating 208 tonnes of uranium materials. Located approximately 75 km northwest of Behchokò, the site can

only be accessed by airplane, helicopter, dog team, skidoo, or canoe.

In 2015, the Tłı́chų Government-Department of Culture and Lands Protection (DCLP) and Aboriginal Affairs and Northern Development Canada (AANDC)’s Contaminants and Remediation Division (CARD) worked together to roll out a Community Engagement plan. It meant months of logistical planning with members of the Kwetłı́zaà Elders Committee, interpreters, environmental monitors and staff from both governments. The Kwetłı́zaà Elders Committee has been meeting over several years to discuss site monitoring results and future plans for Rayrock. This Committee is comprised of Tłı́chų elders from Behchokò, Gamèti, Wekweèti and Whatì with experience on and knowledge of the site, as well as Tłı́chų Government representatives. Its purpose is the exchange of traditional and scientific knowledge with AANDC-CARD, the department responsible for contaminated sites in the Northwest Territories.

In August 2015, after a reconnaissance helicopter tour, a group undertook a watershed tour by canoe along the Marian River. They travelled from the Rayrock Mine Site (Kwetłı́zaà) to Marian Lake to provide Tłı́chų participants a first-hand account of the watershed’s state downstream of Kwetłı́zaà while collecting scientific samples to determine the ecological and environmental conditions of the area. The group ate coney and jackfish while camping at sites to which the Ancestors travelled. During the Tour, participants collected fish and water samples to analyze for contaminants of concern. Over four days, the group of Tłı́chų and AANDC representatives paddled a total of 90 km to end their trip in Behchokò.



Meanwhile, remediation and monitoring work at Kwetı̄ᑦᑦᑦ continues. On October 1, 2015, a group of Tı̄chq Elders and Wek'èezhı̄i Land and Water Board representatives travelled by floatplane to visit the site and perform a Site Blessing. In this traditional ceremony, elders provide advice and best wishes for relatives and friends, pray for safe travel in remote areas of their land, and ask to return home safely. They also ask for the safety of all workers travelling to and working on remediation sites and for workers' safe return to their families, as well as to keep the land, water, and wildlife safe from harm. This is done in the form of a feeding the fire ceremony, where bread and herb (tobacco) offerings and Holy Water are given to Mother Earth. At Kwetı̄ᑦᑦᑦ, a prayer was spoken for all life forms to return to the area and for the land and water to be restored to their natural states.

In this co-presentation, representatives from Tı̄chq Government-DCLP and AANDC-CARD will share findings from the site assessments, ongoing remediation and monitoring, and community engagement with the Kwetı̄ᑦᑦᑦ Elders Committee.

## **GAMMA-RAY SPECTROMETRY AND URANIUM PROSPECTIVITY OF THE 1.9 GA KILOHIGOK PALEOSOL IN MELVILLE SOUND, NUNAVUT**

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Many Precambrian fluvial basins superimposed on the Canadian Shield demonstrated in the past prospectivity for uranium, while others remain largely unexplored. A prominent example of the latter is the Paleoproterozoic Kilohigok Basin, located in the Kitikmeot Region of Nunavut. Its northeastern reach includes a 1 km thick siliciclastic succession (Burnside River Formation) dated to ~1.9 Ga and nonconformably sitting atop Archean (~2.7 Ga) basement rocks of the Canadian Shield. In Melville Sound (~150 km southwest of Cambridge Bay), this nonconformable contact is underlain by a paleosol horizon developed on either granitoid rocks of the Slave Province, or meta-igneous and meta-sedimentary rocks of the Hope Bay greenstone belt. We present stratigraphic and gamma-ray spectrometry data collected along a transect of ~80 km, and discuss the results in terms of uranium prospectivity, and development of Precambrian profiles of sub-aerial alteration.

Well-developed paleo-saprolites derived from granitoid rocks are up to 15 m thick and show a distinctive three-fold zonation in fabric and mineralogy. A lowermost, fresh syenogranite (Kfs±Qz±Pl±Ms) is overlain by a "lower saprolite" devoid of plagioclase, enriched in iron oxide (Qz±Kfs±Ms±Hem), and showing mild fracturing. The overlying "upper saprolite" is devoid of plagioclase and feldspar, shows pervasive sericitization, and is heavily fractured. The Burnside River Formation sharply overlies the paleosol and consists of pebbly sandstone with quartz-overgrowth cement, sericite, and iron-oxide mineralization. Profiles of natural radioactivity indicate that peak concentrations of uranium (up to 30 ppm) feature in the lower saprolite. Lower concentrations of uranium (up to 15 ppm) also occur in a pebbly sandstone that immediately overlies the paleosol.



**ON TRADITIONAL  
KNOWLEDGE RESEARCH,  
INDUSTRIAL DEVELOPMENT  
AND BARREN-GROUND  
CARIBOU**

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A paleo-saprolite is also weakly developed on meta-igneous and meta-sedimentary rocks of the Hope Bay greenstone belt. Examples are up to 5 m thick and display a two-fold zonation. A lower parent rock (typically consisting of gabbro or tholeiitic basalt) shows mild fracturing, and hydrothermal alteration highlighted by iron-oxide enrichment (Cpx±Pl±Hem±Ol). The parent rock is overlain by a saprolite zone composed of highly altered basalt and metapelites. The overlying Burnside River Formation consists of an open framework pebble-conglomerate hosted in erosional depressions interpreted as paleovalleys. Elsewhere, sandstone cemented by quartz overgrowth and iron-oxide directly overlies the saprolite. Profiles of natural radioactivity reveal uranium concentrations of ~10 ppm in the paleovalley-hosted pebble-conglomerate. Elsewhere, background concentrations were recorded from greenstone-derived saprolite and overlying sandstone deposits.

Results indicate that uranium is more likely to be concentrated in saprolite derived from granitoid rocks and developed in mature interfluvial areas that were subject to prolonged sub-aerial exposure. By comparison, poorly developed saprolite underlying a nonconformity with significant erosional topography demonstrate less prospectivity for uranium mineralization. These results shed light on possible styles of uranium mineralization in under-explored sedimentary basins of Arctic Canada.

The range of the Bathurst caribou, on the barrenlands of Northwest Territories, has undergone environmental changes during the last decades; the establishment of large-scale mines, increased exploration, climate change and increased human activity. These factors impact the dynamic between the hunting culture of the indigenous peoples and the barren-ground caribou herds. The direct effect is experienced by hunters in mainly two ways: the dramatic and rapid decline of the Bathurst caribou herd population, which has brought about tight hunting regulation for the indigenous hunters, and large changes to the migration routes of the herds, altering access to hunting.

The Tłı̨chǫ Government established Dedats'eetsaa: the Tłı̨chǫ Research and Training Institute and investigated the cumulative impacts on barren-ground caribou (Bathurst caribou herd) from the traditional knowledge (TK) perspective of the elders and hunters in Wekweètì, a small isolated community on the migration routes of the Bathurst caribou. The TK research is founded on indigenous research methodologies such as participatory-action-research based on indigenous "ways of knowing" with an on-the-land focus to address these bio-cultural issues.

The TK studies demonstrate (1) increasing numbers of abnormal observation in caribou physiology and health, (2) a decrease in quality of forage areas in proximity to the mines, causing (3) altered caribou migration routes to avoid the centers of development activities on the barrenlands, and away from traditional Tlicho hunting grounds. Further, TK studies demonstrate the underlying factors as mainly the activities of the resource extraction industry, the previous out-fitting companies and changed social behavior towards caribou.

As the Tlicho harvesters daily track, hunt, butcher and eat traditional country food, they are the eyes and ears of the land. Continuation to record their intimate knowledge of the habitat and the animals is of vital importance and provides a unique opportunity to understand the dynamic between caribou, their habitat and the areas of development on the Bathurst caribou range. As caribou is the center of the economy of hunting, the continuous challenge is the sustainability to practice the caribou hunting culture.

## **SPECIATION OF ARSENIC IN SOILS ON THE GIANT MINE PROPERTY**

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A suite of 359 soil samples was collected on the Giant mine property at 104 outcrop, forest, and wetland soil sample sites in September and October 2014. Most sample sites were undisturbed by ground-based mining and processing activity. Total elemental analysis by ICP-OES and ICP-MS

following aqua regia digestion indicate that the total arsenic (As) concentrations range from 4.9 µg/g to 17,000 µg/g, and 3 samples have As concentrations greater than 10,000 µg/g As (1 % As). All samples with As greater than 3600 µg/g come from outcrop soil sites and the highest concentrations are from outcrops southeast and northwest of the roaster. At most sites where depth stratified samples were taken, As concentrations decrease sharply with depth. Most As concentrations greater than 1000 µg/g came from samples located <20 cm from the surface, and all samples with As concentrations greater than 3600 µg/g came from samples located <10 cm from the surface.

A subset of 50 samples from 23 sites were selected for As speciation using an automated imaging and analysis technique based on scanning electron microscopy which characterized hundreds of thousands of soil particles in each sample. Selection criteria favored samples with high As concentrations, samples from adjacent depth strata at selected sites, representatives of all soil site types, and samples that covered most of the area of the Giant mine lease. Arsenic trioxide was observed at all 23 sites. The As-hosting species identified included arsenic trioxide, arsenopyrite, arsenic sulfide (likely realgar), and several species with trace amounts of As including roaster-generated iron oxides, iron-arsenic-bearing rims on pyrite and other sulfides, organic material with As, and complex iron oxyhydroxides that include manganese, calcium and aluminum as well as As. A further subset of 24 samples, which contained more than 100 grains of either arsenic trioxide, arsenopyrite, or As-sulfide, and/or high total As concentrations (usually above 3000 µg/g), were used to calculate the distribution of As between the various As-hosting species. For this calculation, three

different values (0.1, 1 and 5%) were assumed for the As concentration in the weathering products (the organics and the iron oxyhydroxides) since these phases remain incompletely characterized.

Application of the automated imaging and analysis method has successfully distinguished natural from anthropogenic As. The distribution of As between different solid species in a soil sample can be calculated, but the uncertainty regarding the concentration of As in weathering products suggests this is best considered semi-quantitative. Our study also confirms our previous research demonstrating that arsenic trioxide is present in undisturbed soils from various locations on the Giant property but restricted to the top few cm of soil. The presence of trace arsenic associated with organics and iron oxyhydroxides suggest that some primary As species are dissolving and As is adsorbed on soil particles.

## SHALE OIL AND SHALE GAS IN CANADA'S NORTH: RECENT FINDINGS AND CURRENT PROJECTS

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In May 2015, the National Energy Board (NEB) and Northwest Territories Geological Survey (NTGS) assessed the Middle Devonian Bluefish Shale of the Mackenzie Plain to contain 46 billion barrels of oil in place and the Middle to Upper Devonian Canol Shale of the Mackenzie Plain to contain 145 billion barrels of oil in place. The amount of marketable (i.e., recoverable) oil was not estimated because well tests are

not yet publicly available and there is still uncertainty about whether these shales are capable of production. However, if only one per cent of the in-place resource could be recovered from the Canol Shale, it would represent a marketable resource of 1.45 billion barrels. As based on the limited geological data available, the analysis assumed that both shales are saturated with oil throughout the study area.

Currently, the NEB is working with the NTGS, as well as the Yukon Geological Survey, the British Columbia Ministry of Natural Gas Development, and the British Columbia Oil and Gas Commission, to evaluate the shale gas resources of the Besa River Formation of the Liard Basin. The Besa River Formation is a thick succession of Devonian- and Mississippian-aged shale with two prospective intervals. The lower interval is equivalent to the producing shales of the Horn River Basin immediately to the east while an interval higher in the rock section contains shale that is stratigraphically equivalent to the Exshaw Formation of Alberta and the Bakken Formation of Saskatchewan.

This talk will summarize the results of the Canol and Bluefish assessment and provide some initial findings on the geological characteristics of the Exshaw-equivalent rocks in the Liard Basin.

## **THE DISTANCE DIVIDE: ADDRESSING INFRASTRUCTURE GAPS TO UNLOCK NORTHERN RESOURCE POTENTIAL**

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This presentation outlines the importance of fiscal policy in supporting exploration and mining in Canada's territories. It presents a broader analysis of the state of the mineral industry in Canada today, and then focuses on the importance of the territories in addressing some key challenges facing the industry. It explains the genesis of a project that outlines the costs of operating in the north and the findings, as well as how infrastructure deficits impact the movement of projects from discovery into production. In conclusion, a discussion of what actions the PDAC believes could be taken to support responsible exploration and mining in the North.

## **TOWARDS A GROUND TEMPERATURE DATABASE FOR THE NORTHWEST TERRITORIES**

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The Northwest Territories Geological Survey (NTGS) is in the initial stages of developing a database of ground temperatures collected across the territory. Knowledge of the ground thermal regime is an essential component of permafrost research, environmental monitoring, resource development projects, and

infrastructure design and performance monitoring. The Government of the Northwest Territories (GNWT) supports the collection of ground temperature data through research projects and infrastructure-related contracts. These research and monitoring programs typically summarize the ground thermal regime in academic publications or reports which are submitted to the GNWT. However, the actual temperature data used to compile the report typically reside with the research institute or consultant, and are often not retained by the GNWT. As ground temperature data are expensive to collect, especially in remote areas, it is beneficial for the GNWT to house these data and make it accessible for use in future projects for the GNWT, the wider research community, industry and other users.

The first step towards housing this information in a database is to establish a metadata reporting template so that ground temperature information is described in a common and standardized way. Although the majority of ground temperature records are accompanied by some form of metadata, the nature of the documented metadata varies widely depending on the purpose of the data collection. For example, engineers and environmental researchers may be interested in different metadata, and may document this information using different terminology. The metadata template was developed and revised based on feedback received from: permafrost researchers and thermal modellers; geotechnical engineers; public and private sector geologists; and civil servants (federal, territorial, and municipal) involved with infrastructure performance monitoring. At this time, we are finalizing the metadata template which is divided into seven sections: (1) Project Details; (2) Location of Ground Temperature Measurements; (3) Installation

of Ground Temperature Cable; (4) Ground Temperature Record; (5) Site Conditions; (6) Permafrost Conditions; and (7) Related Publications and Data.

Once the metadata template has been finalized there are three tasks that will be undertaken. First, a data management plan will be developed. Second, existing ground temperature datasets belonging to the NTGS and our research collaborators will be published as NWT Open Reports so that this information can be accessed as soon as possible. Finally, we will communicate this initiative to other GNWT departments and other northern agencies, and work with them to develop strategies to leverage ground temperature data and make it accessible through this database.

### **DEVELOPING THE FRAMEWORK GEOLOGY FOR MAPPING 3D DISPERSAL PATTERNS IN THE NORTHEASTERN NWT**

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Drift prospecting is a commonly used tool in mineral exploration in Canada's north, and is based on the core concept that mineral material entrained by glaciers will be dispersed down ice from a buried target over a broader area. This concept has been employed to great success in many localities; the Lac de Gras kimberlite field being a prime example. However, factors such as past ice flow history, basal topography, basal thermal regime, and post-glacial reworking can create a complex

system where the basic two dimensional application of the method fails to identify a source from mapped dispersal trains. In an effort to help elucidate these processes an RC drilling campaign was undertaken in March of 2015, combined with coring and field mapping in July of 2015 to characterize the till column across the region. The overall goal of our project is to use subsurface data, such as kimberlite indicator mineral counts and till geochemistry derived from boreholes, in concert with field mapping, to create 1) a broad regional understanding of regional till production and dispersal and; 2) a detailed three-dimensional model of indicator entrainment from a known kimberlite source. This work will allow for the investigation of variables controlling dispersal, such as the effect of bedrock topography at the ice sheet's base and discontinuous till production. In total, this work represents a contribution of ~350 new boreholes, which will yield improved mapping of till thickness, as well contributing a significant dataset of indicator mineral and till geochemistry to the public domain, and a new perspective on the glacial history of the area which is critical for the next phase of exploration.



## OVERVIEW OF 2015 ACTIVITIES AT THE NORTHWEST TERRITORIES GEOLOGICAL SURVEY

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This presentation provides information on 2015 activities and new developments at the Northwest Territories Geological Survey.

On April 1st, 2015, the Northwest Territories Geoscience Office (NTGO) changed its name to the Northwest Territories Geological Survey (NTGS). The new name better reflects the government-focused mandate of this organization and the range of services that it provides. The NTGS continues many of the activities of the NTGO and also continues to grow in a number of areas.

Highlights for 2015 include the start of construction of a new geological materials storage facility and the successful completion of the first year of the Slave Province Surficial Materials and Permafrost Study. The latter project is a two-year, collaborative government –industry – academic research project mainly funded by the Canadian Northern Economic Development Agency. This project advances understanding of glacial history and the impact of climate change to inform future mineral exploration and infrastructure development.

The NTGS also conducted minerals-related field research in the Slave Craton, East Arm Basin, and Cordillera. Through the Geological Survey of Canada's Geo-mapping for Energy and Minerals program, NGS staff also conducted field work in

southeastern NWT, Banks Island, and the Darnley Bay area.

The Petroleum Group initiated a Northwest Territories Petroleum Atlas Scoping Study as well as two unconventional petroleum resource assessments for the Central Mackenzie Valley and Liard Basin in collaboration with the National Energy Board.

This year, the Mining Incentive Program has committed a total of \$400,000 to mineral exploration projects proposed by six licensed NWT prospectors and seven companies. Our staff geophysicist is generating enhancements to geophysical data submitted in company assessment reports. A complete overhaul of NTGS web applications is underway. An additional highlight is the construction of a new database for storage and discovery of archived geological records from past exploration projects and closed mines.

## RETROGRESSIVE THAW SLUMPS AND THE LANDSCAPE SENSITIVITY OF NORTHWESTERN CANADA

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## GAHCHO KUE PROJECT UPDATE PRESENTATION

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Retrogressive thaw slumping is an important driver of geomorphic change in ice-rich, glaciogenic landscapes. Here we summarize research on the processes of thaw slump development, with focus on research from northwestern Canada. In the Peel Plateau, individual disturbances commonly exceed 20 ha in area. These “mega slumps” displace downslope up to  $10^6 \text{ m}^3$  of previously frozen materials, reconfigure slopes and drainage networks, and significantly increase stream sediment and solute loads. The significant acceleration of slump activity has caused this process to become a dominant driver of geomorphic change in several ice-rich environments across the western Arctic. Landsat satellite imagery (1985 to 2011) and high frequency climatic and photographic time-series from the Peel Plateau indicate that an increase in rainfall has accelerated downslope sediment flux from slump scar zones, perpetuating slump activity and intensifying this disturbance regime. Cascading effects include progressive growth of debris tongue deposits comprised of hundreds of thousands of cubic metres of sediment, development of debris dammed lakes, enhanced valley-side erosion and initiation of secondary slumps.

Remotely sensed mapping of slump-impacted terrain across a  $1,275,000 \text{ km}^2$  area of northwestern Canada indicates the close association with ice-rich hummocky moraine landscapes deposited at the margins of the former Laurentide Ice Sheet. This mapping provides a quantitative basis for evaluating the potential for climate-driven landscape change and assessing the spatial distribution of ice-cored permafrost across northwestern Canada.

When it goes into operation in late 2016, the Gahcho Kué Project will be the fourth diamond mine in the Northwest Territories and De Beers' third mine in Canada. Gahcho Kué is a joint venture between De Beers (51%) and Mountain Province Diamonds (49%). De Beers is the operator. It is located at Kennady Lake, about 280 km northeast of Yellowknife and about 80 km southeast of De Beers' Snap Lake Mine.

During a mine life of approximately 12 years, three kimberlite pipes will be mined in sequence, starting with 5034, Hearne, then Tuzo. The deposit was discovered by Mountain Province Diamonds in 1995 and De Beers jointed the joint venture in 1998. Applications for a water licence and land use permit required to build and operate the mine were submitted in 2005. Following an environmental assessment and an environmental impact review the project received its water licence and land use permit and other authorizations in 2014, allowing for the commencement of full-scale construction in 2015.

Gahcho Kué has a life of mine of approximately 12 years during which an average of 4.5 million carats of diamonds will be recovered annually.

The presentation will provide a brief overview of the project history and an update on construction and timeline for commencement of operations, including the capital cost, construction and operations workforce, and De Beers' commitment to sustainable development.

## **POLAR KNOWLEDGE CANADA: ARCTIC SCIENCE AND TECHNOLOGY PROGRAM**

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Polar Knowledge Canada (POLAR) is a Government of Canada agency established on June 1, 2015 to advance Canada's knowledge of the Arctic, strengthen Canadian leadership in polar science and technology (S&T) and direct the operations of a new world-class federal research station being built in Cambridge Bay, Nunavut. The Canadian High Arctic Research Station (CHARS) will complement existing research facilities distributed across Canada's North while conducting its own cross-cutting S&T programs in alignment with Canada's Northern Strategy. This presentation will focus on the priorities of the current five-year S&T program, already underway, many aspects of which have significance for the northern environments and the natural resources development sector. Those priorities are: 1) Alternate and Renewable Energy; 2) Improving Design and Maintenance of Physical Infrastructure for Economic and Social Development; 3) Underwater Situational Awareness; 4) Baseline Information Preparedness for Development; and 5) Predicting the Impacts of Changing Ice, Permafrost and Snow on Shipping, Transportation Infrastructure and Communities. The presentation will briefly expand on (4) and (5), which are of particular importance to the resource sector. The latter aims at spanning the gap between decision makers who need to understand how cryospheric changes will affect their organizations, and the modeling communities who seek to advance basic

process understanding of cryospheric elements. In the case of (4), Baseline Information Preparedness for Development, POLAR is leading an effort to strengthen the information base for assessment, regulatory approvals, and management for resource development. This will increase certainty for industry investment, support tracking the net benefits of a stronger economy, and provide management tools for decision-makers in the private and public sectors. POLAR's Geoscience Forum presentation will also report progress on the construction of the Canadian High Arctic Research Station (CHARS), due to begin operations in 2017.

## **IMPACTS OF WILDFIRES ON TQDZI (BOREAL CARIBOU)**

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Traditional knowledge research of boreal caribou has been undertaken by a number of Aboriginal communities throughout the Canadian boreal forests. Based on a literature review this research is important for habitat use and impacts of industry. Our initial research with the elders and harvesters of Whati` is providing a unique understanding on how tqdzi use particular landscape and associated habitat, and the significance of continuous habitat.

According to the Whati` elders, tqdzi require continuous habitat to accommodate their behaviour and characters as well as their ability to forage and protect their calves. To monitor and manage effectively, accurate Tłchq knowledge (and scientific data) is required on the relationship between wildfires and healthy tqdzi population. Our three-year research and monitoring project is

working towards answering when burn areas will be usable from the perspective of the Tłchq elders and harvesters who know tódzi.

## **TRACE ELEMENT CHEMISTRY AND FLUID INCLUSION SYSTEMATICS OF SKARN MINERALS AT THE CANTUNG W-CU SKARN, NWT**

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The Cantung W-Cu skarn deposit is located within the Canadian Cordillera in the Northwest Territories, approximately 400 km northeast of Whitehorse, Yukon Territory. The deposit is associated with an intrusion which is part of the Tombstone-Tungsten plutonic suite, a series of Mid-Cretaceous granites emplaced into Neoproterozoic rifted margin and Paleozoic passive margin rocks originating from Laurentia. The Cantung W-Cu skarn formed as a result of a contact metasomatic hydrothermal system in which a peraluminous biotite monzogranite intruded into, and reacted with, Lower Cambrian marbles. This produced a zoned array of anhydrous and hydrous reduced skarn (facies assemblages). The most recent resource estimate suggest an indicated resource of 3.84 Mt @ 0.97 % WO<sub>3</sub>.

Previous studies have described skarn styles at Cantung and their associated grades and styles of scheelite mineralization, as well as fluid inclusion studies. However, textural constraints on the fluid inclusions analyzed are oversimplified, limiting the

interpretation of the microthermometric data as a means to delineate specific mineralization events in this multistage skarn development. Additionally, fluid inclusion homogenization temperatures were pressure-corrected using sphalerite geobarometry (from earlier researchers), but the absence of pyrite in equilibrium with sphalerite from all samples suggest this pressure correction may be inaccurate.

Samples were collected from the different skarn facies present within different parts of the deposit with the aim of better understanding the factors controlling scheelite grade and the overall distribution of metals in the hydrous and anhydrous skarn. The primary objective is to determine if the composition (major and trace elements) of skarn minerals (and their fluid inclusions) can be used as exploration vectors towards finding higher grade scheelite mineralization. Characterizing the major and trace element variations in skarn minerals (clinopyroxene, amphibole, apatite) will be accomplished using a combination of SEM (BSE imaging and EDS analyses) and LA ICP-MS methods. A secondary objective is to resolve the timing and conditions of hydrothermal events through the analysis of fluid inclusions with a specific focus on developing a better understanding of the complex skarn paragenesis, as well as the fluid chemistry and multiple overprinting mineralizing events responsible for the development of high grade tungsten intervals. A better understanding of the physiochemical conditions responsible for scheelite precipitation may help to identify prospective areas. Understanding the distribution of scheelite within the different types of skarn may provide insight into potential areas of ore upgrading.

## EXAMINING THE RELATIONSHIP BETWEEN CLIMATE VARIABILITY AND METAL CYCLING IN POCKET LAKE

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The depositional conditions of lakes vary in response to regional climate variability, which affects the abundance of elements of concern (i.e. As, Cu). Regional climate is the product of several large scale oceanic systems (e.g. ENSO, PDO). These systems fluctuate between positive and negative phases over time each phase linked to a range of climate conditions. Understanding how the region responds to past climate variability provides a model for how the region will respond to future climate variability and the fate of metals of concern.

The Yellowknife region is a valuable area for this research as lakes there record both the natural variability of metals and the impacts of previous resource development. Pocket Lake is a small (~4 ha) circular pond within the Yellowknife, NT city limits. Two freeze cores were collected from the deepest part of the lake and both contained a white lamination identified as the White River Ash. The first visible occurrence of the WRA this far east of Mt Logan allows for the construction of an age-depth model based on three independent dating methods (<sup>14</sup>C, <sup>210</sup>Pb and the tephra) making these

cores suitable for carrying out a geochemical time series analysis. Previous work used a paleolimnological approach to reconstruct climate and chemical change over the 3000 year record and identified three groups of elements to be likely influenced by regional climate variability. One group represents catchment hydraulic energy (Ti, Zr, Al, Sc), the second group can be used to track redox conditions (Mo, S, Cu, Fe, Mn, Al, V, Zn), and a third group that showed a visible relationship to past climate events and were elements of chief concern (As, Cu).

Time series analysis revealed that common frequencies within the majority of elements fall between 40-60 years, 70-90 years and 110-150 years. The Pacific Decadal Oscillation is an ocean-atmospheric pattern of variability centered over the Pacific Ocean that is known to influence the climate of North America and has an oscillatory pattern within the range of 40-60 years. Research has shown that the pacemaker of the Pacific Decadal Oscillation is the Gleissberg Cycle one of the slightly longer solar cycles. It has a characteristic split into a low-frequency band signal of 50-80 years and a high frequency signal between 90-140 years. Associating environmental processes to known climate processes aids in the effort of producing models of regional climate variability



## **TERRA INCOGNITA; HIGHLIGHTS FROM THE SOUTH RAE MAPPING PROJECT, SOUTHEAST NWT.**

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The South Rae Province in Northwest Territories (NWT) has seen little research since it was first mapped by canoe and float plane at reconnaissance scale in the 1950-1960s. The new, 3 year, 1:250,000 scale South Rae mapping project of Geological Survey of Canada's Geo-mapping for Energy and Minerals program was initiated in collaboration with the Northwest Territories Geological Survey to improve understanding of its tectonic evolution and economic potential.

Field work in 2015 was focused in NTS 75A and 75B and provides insight on new informally-named, geophysically and isotopically defined domains, each with a distinct record of magmatic and tectonometamorphic events and metallogenic potential.

The Snowbird domain comprises 2.7- 2.55 Ga orthogneiss and <2.02 Ga paragneiss intruded by mafic and ultramafic sills that host Ni-Cu mineralization (Nickel King deposit), all of which record metamorphic conditions of 6-8 kbar and 750-850°C at 1.91 Ga. The Firedrake domain to the west

comprises 2.66 Ga intermediate orthogneiss, mafic to ultramafic rocks and rare paragneiss, all injected by widespread migmatitic granitoids. This domain shows evidence for 1.894 Ga granulite metamorphism at 8-11 kbar and subsequent decompression to 4-6 kbar at amphibolite conditions around 1.84 to 1.80 Ga. Farther west, little is known about the Ena domain in the NWT but in Saskatchewan it includes 3.0 Ga, 2.6 and 2.3 Ga orthogneiss and 1.93 Ga crustal melt. 2.3 and 1.93- 1.82 Ga supracrustal sequences are also present. Finally, the northwestern McCann domain consists of mafic to ultramafic metagabbro injected by tonalitic melt, megacrystic granite, granulite diatexite and paragneiss and 2.15 Ga Orpheous metagabbro dykes. It records high temperature Arrowsmith orogenesis at 2.45-2.3 Ga and 1.88 Ga metamorphism at minimum 8 kbar.

The newly discovered Wholdaia Lake shear zone forms the boundary between the Snowbird and Firedrake domains and has been traced for nearly 100 km. Preliminary observations suggest Firedrake up-to-the-northeast sense of movement accommodating exhumation of its originally deep crustal rocks. The Black Bay fault forms the boundary between the Ena and McCann domains to the west and the Firedrake domain to the east. It is characterized by ductile high strain and appears to be the locus of multiple movements, culminating in dextral oblique shearing.

Multiple types of ore-bearing systems have been explored and mined along the Black Bay fault (U-Au±REE, Hoidas deposit) and Snowbird tectonic zone (Ni-Cu±PGE, Axis Lake deposit) in northern Saskatchewan but their presence and economic potential in NWT are poorly defined. In 2015 several radiometric anomalies were identified along

the Black Bay fault in NWT. Some, closer to the REE Hoidas system, are hosted by felsic alkali intrusions. 100 kilometres further north clinopyroxene-feldspar-allanite-magnetite veins along the fault are hosted in syenite. Preliminary field observations indicate the presence of an extensive alkali magmatic event along the Black Bay fault with a similar mineralization style to Hoidas (REE) and other U-rich hydrothermal systems in northern Saskatchewan. The scope and character of these anomalies will be further defined by targeted mapping and results of a sediment sampling program.

### **THE SURFACE RIGHTS BOARD: CREATING A NEW REGULATORY REGIME FOR LAND ACCESS**

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The Surface Rights Board is a new, independent administrative body being established under the Surface Rights Board Act. The five-member board, appointed by the Government of the Northwest Territories on April 1, 2015, will work to resolve disputes that arise over access to lands. The Board will help to encourage economic development through regulatory certainty, ensuring there is a timely and consistent process to handle the rare occasions where disputes cannot be addressed through negotiated agreements or mediation. The Department of Lands is taking the lead role in this effort, and will provide an update on the current status of the Board and the work being done to ensure it is operational and independent for the start date of April 1, 2016.

### **USING PROPERTY-SCALE SURFICIAL GEOLOGY MAPPING TO REFINE KIMBERLITE INDICATOR MINERAL DISPERSAL PATTERNS AT THE REDEMPTION PROJECT, NWT**

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Surficial sediment (e.g., till) sampling is an effective tool for mineral exploration in the glaciated landscapes of Canada. Dispersal patterns identified through surficial sampling are studied and used to identify their smaller, mineralized bedrock sources. Data compiled from multiple sampling programs, such as those included in the Kimberlite Indicator and Diamond Database (KIDD), can produce misleading dispersal patterns due to variability in sampling and analysis protocols. The accurate delineation of dispersal patterns requires an understanding of the genesis, comparability and distribution of sediment samples on which the dispersal patterns are based.

Using an example from a recent study of the South Coppermine indicator mineral train on the Redemption Project, we demonstrate a method for reducing the variability in the data set that utilizes property-scale surficial geology mapping to systematically filter and normalize the data. The surficial geology mapping identified the nature and distribution of sediments, as well as specific till units that have been reworked to differing degrees by a combination of glacial meltwater, modern drainage and periglacial processes, which can affect the concentration of kimberlite indicator minerals (KIMs). A derivative map depicting till sampling suitability based on



basal till potential and the level of reworking was used to classify and group samples into subset populations, from which less-favourable samples were filtered. KIM counts in the remaining sample data were then leveled (normalized) according to the thickness of the sampled till unit to reduce the bias produced by higher anomalies common to thin till units. The filtered and normalized data produced a sharper, more accurate KIM dispersal pattern and a new basis for interpreting possible provenance envelopes, from which lower-risk exploration targets can be identified.

## QUATERNARY GEOLOGY INTERPRETATION FOR THE SLAVE SURFICIAL MATERIALS AND PERMAFROST STUDY

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The Northwest Territories Geological Survey recently funded a strategic overburden drilling program in the Lac de Gras (NTS 076D) and Alymer Lake (NTS 076C) map areas of the Slave Province, Northwest Territories. This program was designed to help stimulate mineral exploration, and to collect permafrost and geotechnical data required for future infrastructure development. To provide guidance for the drill program and a basis for interpreting the results, we compiled, analyzed and interpreted an unprecedented collection of privately-collected and public data. The data set included extensive LiDAR-derived hillshade models; regional surficial and bedrock geology mapping; and mineralogical, geochemical, grain size and sample description data from surface

sediment (till) samples. Our systematic mapping of the LiDAR coverage area resulted in the identification of 649 linear features, including eskers, meltwater channels, moraines, paleo-shorelines and streamlined bedforms, which strengthened understanding of local ice flow histories and patterns of deglaciation.

Based on a comprehensive review and re-evaluation of the data, we identified six important trends: (1) samples collected from till blankets have lower indicator mineral counts than those collected from till veneers and thick, hummocky till deposits; (2) indicator mineral counts from glaciofluvial sediments were lower and show more subtle anomalies than those from till; (3) the =0.5 mm size-fraction in the mineralogy data set has ~25-40% higher indicator mineral counts than the >0.5 mm size-fraction; (4) when comparing the analytical results of different size fractions, Cr and La concentrations are higher in the clay-sized fraction, while Ba concentrations are higher in the silt- and clay-sized fraction; (5) anomalous Au concentrations in the northern portion of the study area likely represent a lithological change and subsequent glacial dispersion, rather than significant mineralization; and (6) local variations in pyrope and Cr-diopside counts in the study area may affect interpretations of kimberlite indicator mineral dispersal plumes. We also delineated 60 areas of interest that present unique research opportunities, or represent important data gaps that compromise the understanding of glacial history, mineral dispersal and permafrost conditions within the region.

## **DIAVIK MINE OPERATIONAL UPDATE**

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Since 2003 Diavik Diamond Mines Inc. has been mining diamonds from kimberlite pipes located below the waters of Lac de Gras. Diavik produces 6-7 million carats annually and in 2012 Diavik transitioned to a fully underground mine. Diavik's 9.2 megawatt award winning wind farm has confirmed Diavik as a leader in cold climate, off grid renewable energy. Diavik recently began construction on its A21 project, which will bring its fourth kimberlite pipe into production in 2018. This presentation will provide an operational update on the amazing Diavik operation.

## **DEVELOPING AN ALL SEASON ROAD – CHALLENGES AND TRIUMPHS ON THE INUVIK TO TUKTOYAKTUK HIGHWAY**

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The Inuvik to Tuktoyaktuk Highway (ITH) has been an idea for over 50 years. It was only in the past decade that the project gained traction towards becoming a reality. Once constructed, the ITH will be an all-weather link between these two communities in the Mackenzie Delta region of the Northwest Territories. Working collaboratively with our aboriginal partnership company KAVIK-STANTEC in Inuvik, Stantec has completed a variety of tasks ranging from baseline environmental assessment (wildlife, vegetation, and terrain), regulatory support and civil engineering design services.

Crews hit the ground in the winter of 2013/2014 and the project is now entering its third and final winter construction season. The project team (designers, constructors and the Owner) contended with several challenges in bringing the project to fruition. Some of these included:

- Fast track schedule
- Weather constraints
- Data refinements
- Climate change considerations
- Large complexity of the project (requiring collaborative approach)

When completed, the ITH will span over 140 km and provide a vital access route for industry and the public. Stantec will discuss the challenges and triumphs in working on this diverse project working in this remote landscape.

## **WHY DID THE CARIBOU CROSS THE ROAD? – PERMEABILITY OF A MINE ROAD TO BARRENGROUND CARIBOU**

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Camera traps are becoming popular as a monitoring tool for wildlife and are increasingly being used at industrial sites to assess wildlife interactions with infrastructure. To examine how the presence and use of roads may be affecting caribou movement, the Ekati Diamond Mine implemented a monitoring program in 2011 using motion triggered cameras to assess caribou behaviour along project roads.

Caribou numbers, movements, and behaviours were assessed to determine what, if any, effects that project roads have on caribou behaviour:

(1) This study determined temporal and seasonal trends in caribou abundance, which were consistent with data from GPS collaring studies and Traditional Knowledge, with a maximum abundance during late summer (August) and fall.

(2) The most common behaviours at the group level at roads were foraging (135 observations), crossing or crossed the road running (15 observations), walking across/along roads (169 observations), and alert (88 observations).

(3) The frequencies of behaviours of caribou groups was compared adjacent to and at control sites away from the road - behaviour did not vary consistently between these groups (more stressed versus less stressed).

(4) The frequencies of behaviours differed close to the road compared to control sites at the group level; investigating camera, walking, standing, foraging, bedded, and calm behaviours.

(5) Deflections occurred infrequently at project roads, representing <1% of observations. Most deflections were in response to a passing vehicle.

(6) No effect of group size on susceptibility to heavy or light vehicle was detected (i.e., both large and small groups behaved similar to potential vehicles disturbances).

(7) Traffic on the road was relatively consistent in 2011 and 2012 and increased substantially during 2013. The camera effort adjusted number of caribou road crossings did not change with changes in yearly traffic

volumes.

(8) Daily differences in traffic were substantial, but differences in traffic between days was not correlated with the number of caribou observations or the behaviour of caribou, suggesting that the road itself with vehicle traffic deters caribou from crossing the road at a very low rate (less than 1%).

## **MONITORING GRIZZLY BEAR POPULATIONS IN THE CENTRAL CANADIAN ARCTIC TO SUPPORT MANAGEMENT AND CUMULATIVE EFFECTS ASSESSMENT: A DNA BASED APPROACH.**

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We present results from a large scale (16,272 km<sup>2</sup>) regional Grizzly Bear DNA study in the central barrens of the Northwest Territories conducted between 2012 and 2013. The objectives for the two year program were to establish a baseline for the long term regional monitoring of the relative abundance and distribution of grizzly bears.

A total of 1,902 hair samples were collected during the 2012 survey period, representing 112 grizzly bear individuals, including 42 males and 70 females. During the 2013 field program, 4,709 samples were collected. A total of 136 grizzly bears were identified (60

males and 76 females), including 39 that had no previous detections in the regional database (22 males and 17 females). Eight grizzly bears identified in the study area were also detected in other DNA study areas in Nunavut. For the combined DNA dataset, the mean capture probability was 0.22 (range 0.14 – 0.35) in 2012, and 0.35 (range 0.28 – 0.43) in 2013.

Based on Spatially Explicit Capture Recapture analysis, the expected number of male grizzly bears in the region was 59 (95% CI 43 to 81) in 2012 and 87 (95% CI 67 to 113) in 2013. The expected number of females was 102 (95% CI 85 to 122) for both years. The best model based on AIC likelihood estimated female density as 3.60/1,000 km<sup>2</sup> (95% CI 2.85 to 4.56) in 2012 and 3.97/1,000 km<sup>2</sup> (95% CI 3.17 to 4.98) in 2013. Male density was estimated as 1.96/1,000 km<sup>2</sup> (95% CI 1.44 to 2.67) in 2012 and 2.85/1,000 km<sup>2</sup> (95% CI 2.20 to 3.70) in 2013.

These results suggest a stable population in the central barrens of the Northwest Territories relative to estimates for the Slave Geological province in the late 1990's. Through effective partnerships, we demonstrate that DNA mark-recapture programs are a viable method to census grizzly bears in the Arctic to support management and conservation initiatives, and suggest a protocol for implementation.

## DEVELOPMENT OF SOILS AND PLANT COMMUNITIES FOR RECLAMATION IN NORTHERN DIAMOND MINES

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Reclamation research in the north over the past 30 years has primarily focused on oil and gas and transportation corridor disturbances. Among industries, disturbances caused by infrastructure and transportation corridors are similar. However, each industry has its unique by products that determine which reclamation methods are most appropriate to achieve end land use goals and the relative ease of reclamation. The purpose of this research program is to develop methods to enhance revegetation of disturbed sites at diamond mines in the north, in particular to create soil like substrates on sites where soil has been removed with the use of onsite and commercial materials and to reestablish a diverse native plant community. Reclamation substrates include by products from the diamond mining process like crushed rock, till/lake sediment, processed kimberlite and various combinations of till/lake sediment and processed kimberlite. Greenhouse experiments were also conducted at the University of Alberta to test a range of substrates and amendments with potential to aid reclamation in the field. In 2013 and 2014, research sites were established at Diavik Diamond Mine using the best performing substrates to determine the effect of micro topography, addition of organic matter and erosion control on native grass and forb establishment; effective moss propagation techniques and; effective lichen propagation methods. Preliminary results and observations from completed greenhouse experiments and the first two

growing seasons will be discussed. This research directly enhances knowledge and sustainability of northern regions. It will lead to recommendations for enhanced reclamation protocols to be used by industry and government in the north.

## COMPARATIVE STUDY OF COMPOSITION AND OCCURRENCE OF APATITE IN SNAP LAKE AND EKATI KIMBERLITES

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Kimberlites are volcanic ultra-potassic rocks present mostly in cratonic settings and some are diamond bearing. Kimberlite magma is derived from the upper mantle, however, its primary composition is still unknown. Assimilation of mantle and crustal material, loss of volatiles during eruption and high degree of alteration all result in variable compositions of kimberlite magma reaching the surface. Studies have shown that kimberlitic fluid has a significant effect on the quality and preservation of diamonds carried to the surface. By better understanding the primary composition of kimberlites, and the processes that drive kimberlite eruption, we can attempt to gain some diagnostic knowledge of the economic viability of a particular kimberlite. Apatite is a common mineral in kimberlite, which composition is sensitive to volatiles and the presence of magmatic fluid. This study will look at the variation of apatite in kimberlites, how different geology indicates

their different fluid histories, and the potential for using apatite as an indicator of fluid content and composition in kimberlite magma.

The study uses polished sections from different kimberlite lithologies within the Snap Lake kimberlite and from six Ekati Mine kimberlites. Apatite grains were examined using scanning electron microscope (back scatter imaging) and composition was obtained with wavelength-dispersive spectroscopy mode of electron-microprobe analyzes. Snap Lake is a single dyke of coherent kimberlite facies. The dyke intruded in a near-horizontal orientation, and has an average vertical thickness of 2.5 m. There is significant incorporation of crustal material, and the kimberlite is highly altered, possibly a result of interaction with abundant xenoliths. The studied Ekati kimberlites include: two coherent kimberlites - Grizzly and Leslie, and four kimberlites with resedimented volcanoclastic kimberlite facies – Misery, Koala, Panda, and Beartooth. These kimberlites show significant variations in the apatite crystallizing from the melts. At Snap Lake apatite occurs late, interstitially in the groundmass. These anhedral apatites appear to have no zonation, and crystallize around microphenocrysts of olivine and phlogopite. There is also a late component of apatite, possibly associated with carbonate veins that fracture olivine macrocrysts. Sub- to euhedral apatite grains (max 50 µm) crystallize in a carbonate host within a fracture or crack in olivine macrocrysts. In the Ekati kimberlites, apatite is extremely rare to absent in Misery, Panda, and Beartooth kimberlites, but abundant in Grizzly, Koala, and Leslie. Leslie has plenty of euhedral zoned and unzoned apatite associated with monticellite set in carbonate matrix. Grizzly has abundant small (~10 µm) anhedral apatite. Koala contains both



anhedral and euhedral apatite, some of which is zoned. The presentation will report the initial results of this study and possible applications for the behavior of volatiles in the studied kimberlite magmas and examine their relationship with the features of the diamond population.

## **SUPPORTING NORTHERN DEVELOPMENT THROUGH ENVIRONMENTAL MONITORING, CAPACITY BUILDING AND COMMUNITY ENGAGEMENT**

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In northern ecosystems and globally, ERM provides sustainable solutions to various non-technical risk challenges (i.e., health, safety, environment and community) associated with project developments. There is a heightened awareness amongst our clients of a need to develop and maintain a strong social license to operate and ERM supports them to do so.

In the pursuit of sustainable solutions to the influence of project developments, ERM often conducts socio-economic research in the North. Our research is centred on the principle of proactive engagement with key stakeholders including Inuit organizations and local governments. Over the years, ERM and its team members have developed strong relationships in the communities in which we work. The results of our research have been used to inform project decisions and have also helped to build local capacity by involving community members in our research. ERM has also increased local capacity by training local community members to collect environmental field data,

including air and water quality, fish and fish habitat, and wildlife.

Building upon our experience in the North and our well-established expertise, for the past 2 years, ERM and its employees have been providing technical, volunteering and fundraising support in support of an initiative launched to support the development of a commercially viable, sustainable fishery for the Hamlet of Gjoa Haven, NU. This support has been provided through the ERM Foundation in collaboration with the Hunter and Trapper Organization (HTO) of Gjoa Haven and Queen's University. The ERM Foundation, celebrating its 20th year of existence, provides pro bono technical support and grant funding for selected NGOs, community groups and social enterprises that share ERM's commitment to creating a more sustainable world.

ERM has contributed directly to the sustainable fisheries initiative by exploring the traditional, historical and current knowledge of fisheries occurring in and around Gjoa Haven. Using desk-based research paired with results from semi-structured interviews and a focus group, ERM researched and documented local best fishing practices, current challenges and community interests, with the objective of determining the capacities and programs that could be leveraged to develop a viable, sustainable fishery. Training has also been provided to local Inuit on fisheries data collection processes and techniques. The knowledge gained through these initiatives will contribute towards the development of a sustainable fisheries model and establishment of best practices to be replicated in other arctic communities.

## **DISTURBED PERMAFROST ENVIRONMENTS: RESEARCH OPPORTUNITIES**

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We present three research areas from NWT, with broad reaching implications, where recent human and natural disturbances may affect previously impacted permafrost environments, providing new opportunities for understanding.

The first is GNWT Highway 3, crossing the Great Slave Lowland High Boreal ecoregion from Behchoko to Yellowknife, as an example of road infrastructure that traverses a highly heterogeneous landscape with discontinuous permafrost. Permafrost is widespread within undisturbed terrain underlain by fine-grained silty-clay sediments. Construction during the mid-1960s utilized locally available silt and clay excavated from shallow borrow pits, the alignment preferentially crossed natural terrain including peatland and clay-rich terrain, largely avoiding water bodies. Recently (1999 to 2006) major realignments were made to maximize bedrock traverses with new embankments constructed primarily of open graded, blast-rock fill, and to minimize crossing over thaw-sensitive permafrost and thus embankment settlement. However, newly aligned sections extend across natural terrain that includes ponds, peatland, clay-rich terrain, and disturbed terrain including the former highway and associated borrow pits in addition to bedrock. Compared with contemporary conditions at natural sites, the status of environmental changes (permafrost, hydrology, and vegetation) at abandoned and new highway alignments are not well documented. Thus the long-term recovery of

abandoned alignments and fate and environmental impacts of the new alignments are difficult to predict.

The second is the influence of fire on permafrost in previously disturbed areas and infrastructure. Following the forest fires of 2014, preliminary results indicate that fire-induced permafrost degradation is likely to be extensive, and may occur in ice-rich terrain. Permafrost degradation affects hydrological conditions and pathways, and likely the effectiveness of infrastructure. The degree and rate of permafrost recovery are unknown and require long-term consideration.

The last concerns icing development. Icings impinge on the safe operation and management of infrastructure, either directly through accumulation of ice, or indirectly by diversion of flood water. In the North Slave region our research indicates icing distribution and dynamics are related to permafrost and geology. Icing development is linked to precipitation conditions the preceding autumn, but overflow events result from winter air temperature conditions. Others have linked overflow events with increased ground water pressure related to air temperature change, but the physical mechanism is unknown. Better understanding of these processes may be used to develop effective prevention or mitigation measures.

Knowledge gaps identified in these areas may lead to opportunities for future research directions.

## CCGP LAND-BASED PROJECT: ADVANCES AND CHALLENGES IN GEOSCIENTIFIC RESEARCH AND MONITORING

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The Climate Change Geoscience Program (CCGP) land-based project of Natural Resources Canada provides geoscientific expertise on environmental baseline conditions. Primary research, monitoring, and modelling supports informed decision making for resource development and land use. This project provides new geoscientific knowledge to improve our understanding of the distribution and nature of permafrost and seasonal hydrological conditions in the North Slave.

Our research indicates that most permafrost is associated with forest areas, rather than only with peatlands that characterize just 2% of the regional area. Extensive discontinuous permafrost conditions (65% of the regional area) relate primarily to the extent of unconsolidated ice-rich fine-grained sediments, with annual mean ground temperatures ranging from -1.4 °C to 0.0 °C. Monitored permafrost temperatures commonly illustrate thermal degradation in both natural and disturbed terrain. Modelling indicates substantial reductions of permafrost extent driven by climate-change, with a gradual transition by AD 2100 to isolated permafrost retained primarily within peatlands. Modelling also indicates that on average, fire accelerates permafrost disappearance by 5 years, though permafrost in forest areas is more sensitive to fire than in tundra and peatlands. Icings are a

geohazard indicative of winter hydrological conditions. They develop over the winter by freezing successive overflows of groundwater to the surface, and we mapped 5500 in the study region. Mapped icings indicate the extent of groundwater springs in the region, information useful for hydrological monitoring of seasonal ground water flow and chemistry. Regional interannual variation is driven by winter warming intervals and antecedent autumn precipitation, but this is moderated by geological conditions that vary intra-regionally. Future icings may develop less frequently due to decreasing winter warming intervals, but increasing autumn rainfall may increase icing density in areas dominated by bedrock outcrop.

Overall, our key finding is that substantial changes in permafrost and seasonal hydrological conditions are likely to occur naturally within the lifetime of many projects. Understanding the direct impacts from those changes requires future research to address a number of challenges. Driven by surface temperature change, the rate of permafrost degradation is regulated by surface organic layer thickness, but also by ground ice content, which also determines the degree of terrain sensitivity to thaw with indirect effects related to water quality and catchment-scale hydrology. However, unlike organic layer thickness, ground ice conditions are poorly understood. In reality, degradation of discontinuous permafrost is also driven by changes in heat flow adjacent to and beneath permafrost bodies, thus permafrost modelling should explicitly consider 3-D boundary conditions. Soil moisture strongly influences heat flow and ground temperatures, but the dynamic relations are not well quantified. Icing activity is likely affected by regional meteorological differences, but at present this variation cannot be accounted for due to

a lack of field data for validation. Finally, the physical process linking winter air temperature warming to overflow is not known, but this understanding would greatly assist with prevention and mitigation measures.

**HIGH SPATIO-TEMPORAL  
RESOLUTION ASSESSMENT OF  
ARCELLININA (TESTATE  
AMOEBAE) AS BIO-  
INDICATORS OF LEGACY  
MINE CONTAMINATION IN  
THE CANADIAN SUBARCTIC:  
IMPLICATIONS FOR  
ENVIRONMENTAL  
MONITORING**

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For seven decades (1948-2004), the gold mining industry was a substantial economic driver for the Northwest Territories (NT), with major mines like Con, Giant (GM) and Discovery mines, generating \$5,510 million in revenues for the territory. The operations of these mines, especially GM, left an enormous legacy of contamination by arsenic (As) and serious environmental concerns. This led to the closure of GM in 2004 and the initiation of the GM Remediation Project (estimated cost of ~ \$1 billion). While current assessment of As levels is largely focused on targeted areas of concern, little attention has been devoted to evaluating the impact of As contamination on lacustrine sediments beyond these areas.

With the potential of developing new gold mines along the productive Yellowknife Greenstone Belt, a multidisciplinary and quantitative investigation of lacustrine sediments around GM is critical to provide mine developers, planners and policy makers with: (1) a cost-effective and reliable tool for assessing the intensity of As contamination and remediation rates in impacted lakes, and (2) quantitative geochemical background and baselines data for As in the region.

One such cost-effective and reliable tool that is sensitive to As is Arcellinina (or testate amoebae), which is a group of well-preserved, benthic protist. Their rapid reproduction, abundance and sensitivity to an array of environmental changes render them particularly useful for environmental monitoring and assessment of the health of lacustrine systems. For my M.Sc. thesis I studied the spatial relationship between arcellinids and As contamination in lake sediment samples (n=61) collected in August 2012 from 59 lakes spanning a radius of ~30 km around GM. The results of this research revealed a strong correlation between high levels of As and stress-indicating arcellinid taxa, thus providing new insight into the sensitivity of Arcellinina to As and indicating the suitability of using the group as a bio-indicators for assessing the ecological impact of As contamination on lakes.

To build upon this line of research, Arcellinina, As and other environmental variables will be examined in an additional set of surface sediment samples (n=32) and freeze cores collected from the region around GM and Daigle Lake during the 2014 and 2015 field seasons, respectively. The additional surface sediment samples will aid in enhancing the spatial coverage of the 2012 survey, which is critical for

mapping As distribution in the region. Freeze coring was used to capture undisturbed, high resolution sedimentary sequences that will aid in: (1) examining the temporal response of arcellinid to As prior, during and following the GM operation, and (2) determining geochemical baseline conditions of As in the region. Multivariate analyses will be performed on all proxies to quantify the spatio-temporal relationship between arcellinids, As and other possible controls.

Results from this research will provide mine developers and planners with a much needed tool for assessing the intensity of As contamination and rates of remediation in impacted lakes in the YK region. Such results will also have significant implications for other impacted regions around the world due to the cosmopolitan nature of arcellinids.

## **MITIGATING THE EFFECTS OF ROADS ON CARIBOU MIGRATORY MOVEMENTS AND BEHAVIOUR: A NOVEL APPROACH FROM THE JAY PROJECT**

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The Ekati Diamond Mine (Ekati Mine) is owned and operated by Dominion Diamond Ekati Corporation (Dominion Diamond), and is located in the Slave Geological Province of the Northwest Territories, approximately 300 km northeast of Yellowknife. Dominion Diamond is also

proposing to develop the Jay kimberlite pipe, which is expected to extend the life of the mine by 10 years or more. The Jay Project is located in the southeastern portion of the Ekati Mine claim block, approximately 25 km from the main facilities and 7 km northeast of the Misery Pit. The Project will require a road from the existing Misery Road to the south abutment of Jay Dike. This will be referred to as the Jay Road, which will be approximately 5.1 km long.

This proposed road will cross through an area of land that has historically been an important migration route for the Bathurst caribou herd. There is a great deal of concern about the potential effects this road could have on caribou. During the Jay Project Technical Sessions in April 2015, Dominion Diamond made the commitment to provide a Caribou Road Mitigation Plan (CRMP) that gives further details on mitigation strategies to reduce the impacts from the Jay and Misery roads. This is the first road mitigation plan of its kind in the Northwest Territories, which included several revisions following engagement with communities, government, technical specialists for the Mackenzie Valley Environmental Impact Review Board, and the Independent Environmental Monitoring Agency.

The objective of the CRMP is to avoid and minimize (i.e., reduce) the risk of caribou and other wildlife mortalities from traffic, the barrier effect of the Jay and Misery roads (and other Ekati Mine roads) to caribou movement and migration, and limit the effect of sensory disturbance from roads and traffic. A step-wise or hierarchical approach that increases mitigation and monitoring was developed. Four levels of mitigation and monitoring are proposed in an effort to streamline the response protocols for



operators and employees at the mine site. It also mirrors existing procedures in place at the Ekati Mine and can be readily applied to other developments requiring roads.

**NORTHQUEST LTD. PISTOL  
BAY GOLD PROJECT:  
INTRUSION-HOSTED GOLD IN  
KAMINAK-TYPE GREENSTONE  
BELT, EASTERN NUNAVUT**

**NORTH, J.N.**

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The Pistol Bay Project is located in eastern Nunavut, on the west coast of Hudson Bay, 60 km southwest of Rankin Inlet. The project is within the Archean Rankin-Ennadai greenstone terrain of the Hearne Craton and covers a 90 kilometre strike length of a west-trending series of surface gold occurrences, and gold zones intersected in drill holes by Northquest Ltd., known as the Pistol Bay Trend. The Pistol Bay Trend is parallel to, and 80 kilometres south of, the Meliadine Trend of Agnico Eagle Mines, which reportedly contains 3.0 million ounces of gold reserves, plus 2.2 million ounces indicated and 2.9 million ounces inferred ([www.agnico-eagle.com](http://www.agnico-eagle.com)). Since field operations commenced in June 2011, and with exploration expenditures of approximately \$15 million to the end of 2015, Northquest has obtained economically interesting drilling results at several targets over a 20 kilometre long strike length of the Pistol Bay Trend. The most advanced target is the Vickers gold zone.

The Pistol Bay Project is in a Kaminak-type belt of the more widespread Rankin-Ennadai terrain. The belt has a fully fractionated volcanic sequence of basalt to rhyolite, abundant siliceous epiclastic rocks, banded iron formation, and numerous plutons varying in composition from granite to

gabbro. Age determinations by Northquest for the plutons and volcanic rocks are 2,695 to 2,668 Ma. The most advanced target is the Vickers Target, where 17,195 metres of drilling in 69 drill holes has yielded some of the best exploration gold intersections obtained in Canada within recent memory including 8.23 grams per tonne over 156.5 m and 5.39 grams per tonne over 164.0 metres in 2012. The gold is concentrated in a siliceous alteration zone in the margin and footwall of a fractionated intrusion, and is similar to the gold concentrations in the Golden Mile Dolerite, in the Yilgarn Craton of Western Australia. The Vickers gold zone is approximately 20 to 100 metres wide, at least 600 metres long, and has been intersected from surface to a vertical depth of 300 metres. The gold occurs as free gold and fine-grained gold associated with secondary, hydrothermal silica and disseminated pyrite with minor arsenopyrite. This mode of gold concentration is very different from gold deposits elsewhere in the Archean cratons of the Canadian Arctic that are mostly in narrow, highly sulphidized ribbons of banded iron formation or in classical vein arrays. The mode of gold concentration, shape, and geometry of the Vickers gold zone suggest very strongly that the development of the deposit will take the form of an open pit with a very low stripping ratio and with high gold recovery from metallurgically simple ore.

## **EKATI LONG LAKE CONTAINMENT FACILITY RECLAMATION RESEARCH**

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The Ekati Diamond Mine is a surface and underground diamond mine operated by Dominion Diamond Ekati Corporation. It is located near the Lac de Gras Northwest Territories, Canada approximately 300 km north of Yellowknife and roughly 200 km south of the Arctic Circle. The Ekati Long Lake Containment Facility (LLCF) is a five celled containment area for storage of processed kimberlite generated during the processing and extraction of diamonds from kimberlite ore. The LLCF has been in operation since 1998 and deposition of processed kimberlite has occurred within the three northern cells with the remaining two cells being used for water quality “polishing” to help meet discharge criteria.

The Interim Closure and Reclamation Plan for Ekati outlines a plan to cover the LLCF kimberlite surface with a combination of rock and vegetation. The cover system looks to fulfill the closure objective of physically stabilizing the processed kimberlite and creating a landscape safe for wildlife and human use. Cell B of the LLCF has reached its capacity and is being used as a reclamation research area. The purpose of the reclamation research is to identify a long term cover design that can be expanded to the whole LLCF.

A winter drilling investigation in Cell B of the LLCF was undertaken in 2013. The objective of the investigation was to characterize the processed kimberlite and its

porewater chemistry. Results from the investigation indicated that permafrost has aggraded into the kimberlite and surface zone pore water concentrations were higher when compared to process plant discharge.

In fall of 2013 various areas of Cell B were seeded with annual and perennial vegetation ground covers. In the winter of 2013 rock was placed in various configurations within the seeded areas to evaluate its effects on vegetation growth and erosion control. Further seeding of Cell B was completed in the summers of 2014 and 2015. Seed from a variety of sources that includes locally harvested and commercially available native plants and farm crops was applied at different rates using different seeding techniques. A total of 25 hectares has been seeded in Cell B since the fall of 2013 and monitoring results are positive regarding establishment of long term ground cover on the kimberlite.

## **OVERVIEW 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.

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 2015, the GEM program conducted 17 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.

## **GOLDSIM WATER BALANCE MODELING OF WASTE ROCK PILES, EKATI WASTE ROCK STORAGE AREA (EKATI WRSA) - NORTHWEST TERRITORIES**

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The Ekati Waste Rock Storage Piles (WRSA) water balance model was developed in Goldsim as a module designed to support water quality estimates. The water balance module accounts for direct precipitation, snowmelt, seepage, runoff, and delays to flow within the WRSA.

As the Ekati Mine is located within a climate zone of continuous permafrost, a portion of the water infiltrating the WRSA's becomes trapped within the waste rock as ice when it encounters sub-freezing internal temperatures. Seepage leaching from the WRSAs is thus limited to the outer surface of the WRSAs (active layer) where water produced by melting of seasonal surficial ice and snow. The active layer was modeled by detaining all water in the WRSA from October to the end of June. After June the water was released from the layer using a delay function, which is described below.

The model divides seepage and runoff into three physically-based flow paths.

- The primary flow path is of water that falls infiltrates vertically through the waste rock until it encounters an impermeable lens of ice-saturate rock, and travels horizontally, to ultimately emerge at the toe of the WRSAs.

- The secondary flow path is water that falls on the outer slopes of the WRSAs and seeps under the outer slopes to the toe.
- The third flow path is also of water that falls on the outer slopes of the WRSAs and travels along the surface of the WRSA to the toe as runoff.

Water losses were accounted at the surface of the pile prior to infiltration and within the pile as follows;

- water losses from evaporation is represented by a runoff coefficients; and
- water loss to the pile is modeled based on a percentage of volume of waste rock. As each WRSA is saturation flows exiting the pile increase.

Flat infiltration is the slowest flow path and creates base flows that maintain flows out of the WRSAs during late summer and early winter periods. The slopes seepage is released more slowly over several days or weeks. While slopes runoff is the fastest flow path creating storm peaks during rainfall events. Results of the total WRSA discharge are a constant slow outflow at the toe with small increases due to precipitation events and the freshet, which is consistent with observations of waste rock drainage.

Flows are attenuated using a time delay, which was simulated for each flow path using an Erlang function. The Erlang function refers to a two-parameter Gaussian distribution, where the shape parameter  $n$  is an integer. Hydrologically, the parameter  $n$  corresponds to the number of hypothetical linear reservoirs (Nash 1957). For the slopes runoff,  $n = 1$  is assumed, which gives an exponential distribution. For the flats infiltration and slope seepage  $n = 2$  is assumed, which gives a typical unit hydrograph shape with a delayed peak flow. The value of the lag parameter for each

component was determined through model calibration.

## **PETROLOGY, GEOCHEMISTRY, AND U-PB GEOCHRONOLOGY OF THE PRESTIGE PLUTON AND RELATED PEGMATITES, NWT : PETROGENETIC IMPLICATIONS**

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The Yellowknife Pegmatite Field encompasses an area of 12,000 km<sup>2</sup> north of Great Slave Lake, and is host to both LCT family rare-element and simple pegmatites that are associated with granitoid batholiths. In the northwestern quadrant of the field lies the Prestige pluton, one of 14 muscovite-biotite S-type granites of the Prosperous Suite; it is ~4 km in diameter, surrounded by quartz-plagioclase-biotite-muscovite schist of the Burwash Formation. No previous dating of the Prestige pluton has been completed; however, it has been assumed to be coeval with the Prosperous Suite, which has a monazite U-Pb age of  $2.596 \pm 0.002$  Ga by dating of the Sparrow Lake pluton. Previous lithogeochemical results on the Prestige Pluton indicate a relatively high concentration of Li (mean of 700 ppm), prompting economic interest in this pluton. Barren quartz-feldspar pegmatite dykes intrude the Prestige Granite (intrapluton pegmatites) and also occur in the supracrustal rock. Interpluton beryl-columbite subtype pegmatite dykes are hosted primarily within the Burwash metasedimentary rocks, particularly within the southwest corner of the field area and

locally contain rare-element minerals, such as tourmaline (schorl), white-yellow heliodore beryl, and rare columbite-tantalite; however, pegmatites containing beryl and tourmaline have also been identified within the granite.

In the LCT pegmatite family, an increase in Li, Cs, Rb, Ta, and Sn and sequential decreases in ratios such as K/Rb, K/Cs, Sr/Rb in minerals and whole rock data is typical as the degree of fractionation increases. These fractionation indices have been evaluated using bulk-rock geochemistry to determine how evolved the granitic S-type igneous system is, and how the pegmatite dykes vary spatially. The intra- and interpluton pegmatites are relatively enriched in incompatible elements, with averages of 21.0 ppm Cs, 9.5 ppm Ta, 453 ppm Rb, 23 ppm Sn, 4.9 ppm U, and 2.3 ppm Th; granite averages of 7.6 ppm Cs, 1.5 ppm Ta, 237 ppm Rb, 5.7 ppm Sn, 5.4 ppm U, and 16.1 ppm Th. The K/Rb and K/Cs ratios indicate interpluton pegmatites reach the greatest level of fractionation, with averages of 67 and 2104, relative to averages of 81 and 1697 for the intrapluton pegmatites and 177 and 4333 for the granite. The observed spatial variation is supported by new trace-element compositional data on muscovite. These results are coupled with temporal constraints determined by monazite U-Pb geochronology via in situ LA ICP-MS to determine if the relationships between the dykes and granites are upheld by the accepted single cogenetic intrusion and dyking model.

## REMOVING THE COBWEBS FROM PAST EXPLORATION AND MINING RESEARCH

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The Northwest Territories Geological Survey (NTGS) is working on developing a searchable database for discovering geological records from past exploration projects and closed mines. The archives represent millions of dollars of exploration and mining research, and contain original data, such as field notes and maps, air photos, drill logs and assay results, onion skin drawings, linen maps, photographs, annual reports, news clippings, and press releases. These materials are mostly from the 1970's and 1980's, but some date back to the mid-1930's. Currently, many of the physical files are stored in dusty, old cardboard boxes and filing cabinets that barely open. Some of the material is kept in an unheated warehouse, which is not ideal for preservation or year-round accessibility. Largely unorganized and unsearchable, there is no way to find anything easily and periodic requests to view the archives have resulted in more disorganization and randomly scanned files. Over the years, there have been sporadic initiatives to deal with this material; however no useful database was ever created. In 2015, the NTGS began a formal project to develop a digital database so that the information in the archives can be easily accessed to support future geoscience research and mineral exploration in the Northwest Territories. The NTGS is working on this initiative in collaboration with the Informatics Shared Service Centre - ENR/ITI/Lands, and a contractor specializing in this type of work.



## **THE NWT INVENTORY OF LANDSCAPE CHANGE: A WEB- ACCESSIBLE PLATFORM FOR VIEWING AND MANAGING NATURAL AND HUMAN DISTURBANCE INFORMATION**

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Information on the location and extent of past development and natural disturbance is required by regulators, industry, co-management boards, wildlife managers, communities and other stakeholders to make effective decisions about future development in the Northwest Territories (NWT). It is currently the responsibility of the interested party to compile information on developments and natural disturbances in the area of interest in order to be able to conduct cumulative effects assessment. The lack of a comprehensive and standardized disturbance dataset leads to inconsistencies in assessments, and subsequently leads to challenges in wildlife management and regulatory and land use planning processes.

This presentation will describe recent efforts by the NWT Cumulative Impact Monitoring Program to move towards a standardized, publically accessible database of human and natural disturbance in the NWT. Specifically, we will highlight the comprehensive human disturbance mapping approach that we have used in 4 of 5 administrative regions of the NWT and the newly released Inventory of Landscape Change (ILC) webviewer. A multiproxy approach using existing geospatial datasets and permitting records from regulatory

agencies in the Northwest Territories was 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 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 500 human activities within the NWT between 2000 and present. The 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 Inventory of Landscape Change webviewer is a web-based application that provides access to over 50 previously developed geospatial datasets from a range of data providers. Users can add/subtract these layers from the webviewer to explore the extent of disturbance features in their area of interest. An integrated toolbar allows users to perform simple analytical functions, including querying of data by date and disturbance type. Users can also extract layers of interest so that additional higher level analyses can be performed in a GIS. A built-in feedback form allows users to highlight errors and provide comments on specific datasets or on the ILC webviewer in general. A regular update schedule will ensure that feedback is integrated into the webviewer on a timely basis.

Initiatives 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 these products so that we continue to move

towards a robust database of human and natural disturbance in the NWT.

## THE CONCENTRATION OF ARSENIC IN LAKES OF THE YELLOWKNIFE AREA

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The Cumulative Impact Monitoring Program and the Geological Survey of Canada are 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 an understanding of regional water and sediment conditions in the area. 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 and sediment chemistry results from the survey indicated higher concentrations of arsenic (As) in lakes within 17 km of

Giant Mine than in the rest of the study area. Arsenic concentrations were highest in small lakes (< 100 ha) that were downwind and proximal to the historic stacks, suggesting a gradient in impact from historic roaster operations at Giant Mine consistent with predominant wind direction in the region. Concentrations of As exceeded federal and Yellowknife specific guidelines for many of the lakes sampled within 17 km of the roaster stacks, and in some lakes were more than 60 times the federal drinking water guideline of 10 ppb and 60 times the Yellowknife specific sediment quality remediation guideline of 150 ppm. 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). In lake sediments median concentration of As was 107.9 ppm (max = 10 000+ ppm; min = 6.3 ppm). The distance and direction of lakes from the historic roaster stacks was clearly associated with the concentration of As in surface waters and lake sediments in the area. However, within the area of elevated As there was substantial between-lake variation in water and sediment 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 more than 75 years of mining.

## CURRENT USE OF GEOPHYSICAL METHODS TO IDENTIFY AND MONITOR PERMAFROST RELATED THAW SETTLEMENT IN THE NORTH

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The use of Geophysics to identify thaw settlement features is not new and has been practised for the last 40 years.

Recent developments of note have seen an integrated approach marrying the results of several different geophysical methods with a GIS database approach to organising the results. This allows the information collected, to be spatially referenced and tracked together with other site information. This approach has a number of advantages, providing a more complete overview of the site conditions as well as means to track whether mitigation procedures are successful. The data can also be used to identify other potential problem areas prior to there being significant surface expression of settlement based on key indicators that may be site specific.

Three primary geophysical methods are used in mapping permafrost related thaw settlement, Ground Penetrating Radar (GPR) Capacitively Coupled Resistivity (CCR) and Multi-Array Analysis of Surface Waves (MASW). This presentation will provide a layman's overview of these geophysical methods and why they are suited to mapping permafrost related thaw settlement. This discussion will be illustrated with examples from recent projects completed with the North West Territories Airports Division, Department of Transportation at the Inuvik and Hay River airports.

## USING EARTH SCIENCE DATA TO INFORM RISK ASSESSMENTS AND MANAGEMENT DECISIONS AT HISTORICAL GOLD MINES IN NOVA SCOTIA

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Gold mines frequently have high arsenic (As) concentrations in mine wastes and nearby soils, sediments, streams, and groundwater. Recent studies at historical gold mines in Nova Scotia have shown that As is present in tailings at concentrations hundreds to thousands of times the Canadian Soil Quality Guideline (12 mg/kg), which may pose a risk to ecosystems and human health. Following the closure of most mines in the mid-1940s, ongoing residential development, industrial construction, and recreational activities have increased the potential for human exposure to these mine wastes. In 2005, the Province of Nova Scotia established the Historic Gold Mines Advisory Committee to better understand these risks and to help guide land-use decisions

(<http://www.gov.ns.ca/nse/contaminatedsites/goldmines.asp>). Detailed studies have been carried out to examine the concentration, solid-phase speciation and bioaccessibility of As in tailings, airborne particulates and forest soils near these sites to clarify the spatial extent of mine tailings, the mineral hosts for As, and the fate of windblown tailings dusts. Environmental assessments have also been completed at two mines

where dusty, high-As tailings are located close to residential areas and are frequently used for racing off-road vehicles.

Mineralogical characterization of the tailings and windblown dusts show that As is hosted in arsenopyrite and a variety of weathering-related secondary phases including scorodite ( $\text{FeAsO}_4 \cdot 2\text{H}_2\text{O}$ ), Ca-Fe arsenates, and As bound to Fe oxides. These phases have varying solubilities that strongly influence the environmental fate and bioaccessibility of As in the tailings. Samples of surface soil (0-5 cm) collected within two districts show that the upper limit of natural As concentrations ranges from 31 to 139 mg/kg. In general, the concentrations of As are higher down-ice of the ore zones in these gold districts, reflecting glacial erosion and transport of mineralized bedrock containing arsenopyrite and other sulphide minerals.

Results from this research have been used by risk assessors and government regulators to evaluate the human health risks associated with exposure to As-bearing tailings and soils, and to help guide management actions. This presentation will describe specifically how geochemical, mineralogical, and bioaccessibility data can be used to inform environmental management decisions in historical gold mining districts across Canada.

## **WHO KILLED FRAME LAKE? PROGRESS REPORT ON EFFORTS TO REHABILITATE AN IMPORTANT YELLOWKNIFE RECREATION AREA**

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Frame Lake, located near the Yellowknife city center, is an important destination for local residents and tourists. It is ringed by the Frame Lake Trail, with city hall and the territorial legislative assembly building on its shoreline. Prior to the early 1970s, the lake reportedly supported a fish population, and McNiven Beach was a well-known destination for swimmers. From traditional knowledge the population was large enough in the lake to support a fishing camp prior to the 1930s. Water quality in the lake deteriorated through the years, as a result of air fall from mine operations, and from the dumping of mine waste and sewage into the lake. The impact of urbanization coupled with restrictions to outflow following construction of a causeway led to



nutrification. The increased availability of nutrients resulted in luxuriant aquatic plant growth, which subsequently led to fish winter kill as decomposing plants depleted lake oxygen levels to create dysoxic conditions. The elimination of a year round fish population led to a significant change in lake ecology, notably the rise a significant Euhirudinea population, which effectively put a stop to recreational swimming. The present-day lake is floored by a black, foul smelling and highly As contaminated sediment layer up to 0.5 m thick.

The research mandate is to: 1) establish a chronology correlated with a multi-proxy analysis of freeze cores and modern sediments; 2) assess modern-day and past lake ecology to determine baseline limnological conditions and timing of different phases of lake degradation; 3) determine the general suitability of the lake to support fish in the past; and 4) provide guidance for development of a plan to rehabilitate the lake to support a year-round fish population, and re-establishment of McNiven Beach as a recreational destination.

One possible lake rehabilitation strategy is to dredge the contaminated horizon. For any dredging effort to be successful an accurate determination of the spatial extent, thickness and quantification of any stratigraphic variability in the levels of As present is required. A series of Glew cores were collected along a transect that spanned the length of the lake to characterize intra-lake variation in the stratigraphic thickness of the contaminated horizon. Shallow sub-bottom seismic profiling obtained using a HDS8 Lowrance side-scan sonar and SyQwest StrataBox subbottom profiler was carried out along 14 transects and ground-truthed against the Glew core stratigraphy. Interpolative maps of thickness and

estimation of the volume of the contaminated horizon were generated using the Geospatial Analysis toolbox in ArcMap 11. Tentative results indicate that the total volume of contaminated sediments in the lake is ~ 230,000 m<sup>3</sup>, divided into five distinct horizons. The thickest layers of contaminated sediment are found in the SW corner of the southern lake basin. This result supports anecdotal reports of sewage and mine waste being dumped into this part of the lake. Levels of As in the substrate vary down core, and when compared against <sup>210</sup>Pb dating results, closely correlate with 1) mining related air fall of As in the early days of mining, 2) dumping of contaminated sediment into the lake, and 3) construction events around the lake.

## USING THE PAST TO INFORM THE FUTURE: A PALEOECOLOGICAL PERSPECTIVE OF CLIMATE AND ENVIRONMENTAL CHANGE IN THE NORTHWEST TERRITORIES

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The impacts of climate change are predicted to alter both the frequency and severity of disturbances across the globe. Across boreal regions of the sub-Arctic, the leading causes of disturbance are wildfire and insect outbreaks and these are predicted to become more frequent and severe during the current century. Drought is also an important agent of disturbance that impacts many regions throughout the world. However, drought is not a disturbance often associated with the Northwest Territories. The past two years, however, have shattered this perception as low winter precipitation and non-existent spring/summer rains have caused lake levels



to decline and wildfire frequency and severity to increase. Aside from this recent two-year period, little is known about the propensity for drought or drought-like conditions in the Northwest Territories. Climate records from the region only provide information back to the 1940s. Therefore, a long-term perspective of climate and drought in the Northwest Territories is lacking. Paleoecology provides an opportunity to examine past climatic conditions and the occurrence of disturbances during a longer time span than instrumental records can provide. Dendrochronology, the science of dating and analyzing tree ring growth records can provide annually-resolved data extending back 100s to 1000s of years. Paleolimnology examines microfossils that are preserved in sediment from the bottom of lakes and can provide additional information over timescales of 1000s to 10000s of years, albeit not normally at annual resolution.

At twelve sites in the Yellowknife region, approximately 50 jack pine (*Pinus banksiana*) trees growing on rock outcrops were sampled. A tree-ring chronology was developed for each site. The average chronology length for the twelve sites is approximately 180 years, spanning the period 1825–2005. The longest chronology developed covered the time period from 1679–2005, while the shortest only went back in time to 1936. Each chronology from the twelve individual sites is significantly correlated with June, total May–July, June–July, and June–August precipitation, although relations with the single month of June are strongest. The twelve individual chronologies showed strong agreement between them and thus were averaged together to create a single chronology for the Yellowknife region. June precipitation was reconstructed using this regionally averaged tree-ring chronology. The reconstruction

indicates periods of lower than average June precipitation occurred in 1927–1979, 1880–1893, 1842–1865, 1801–1821, 1776–1796, and 1698–1739. Higher than average June precipitation occurred between 1980–1995, 1890–1926, 1822–1841, 1756–1775, and 1687–1697. Throughout the period of the reconstruction there is agreement between the reconstructed June precipitation in Yellowknife and other records of precipitation and drought from other parts of western North America, suggesting that the controls on precipitation in Yellowknife are probably controlled by large-scale atmospheric circulation patterns.

## **GIANT MINE REMEDIATION PROJECT CONSULTATION & ENGAGEMENT IN PROJECT PLANNING**

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Following the discovery of gold in the Yellowknife, Northwest Territories area, Giant Mine officially opened in 1948. After the mine closed in 2004 the care and control of the mine fell to the Department of Aboriginal Affairs and Northern Development Canada, and attention focused on the environmental issues left behind, including the arsenic trioxide stored in underground chambers. The Giant Mine Remediation Project was created in 2005 with the overall goal to protect human health and safety, and the environment. The site lies within the Mackenzie Valley watershed, and is regulated by the Mackenzie Valley Resource Management Act (MVRMA). The MVRMA is federal legislation aimed at protecting the lands and waters within the Mackenzie Valley watershed. Since the site is under the care and custodianship of AANDC, it is also

subject to other federal acts, such as the Canadian Environmental Protection Act, the Fisheries Act and the Migratory Birds Convention Act, among others.

Giant Mine is also within the Akaitcho Dene asserted territory and is in the near vicinity of the Yellowknives Dene First Nation (YKDFN) communities of N'dilo and Dettah. Giant Mine is also within the traditional land use area of the Tlicho, known as Mowhi Gogha De Niitlee, and it falls within the provisions of the Tlicho Agreement (2003).

It is also situated within the municipal boundaries of the City of Yellowknife, and so is impacted by the City's bylaws and permitting requirements.

The site has always had a high profile within the community, with special interest groups, and with the local media for both positive and negative reasons. This interest, along with specific requirements established through the MVRMA and other acts, agreements, and by-laws make it incumbent on the project team to engage with community members and other stakeholders when determining and implementing the final remediation plan for the site. This presentation will explore the methods the project team will take to fulfill this requirement, and discuss the challenges this can present in order to deliver a successful project to remediate the Giant Mine site.

## **A GEOCHEMICAL STUDY OF DIAMOND INDICATOR MINERALS FROM THE NWT INTERIOR PLATFORM**

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The Central Mackenzie Valley (CMV) area of the Northwest Territories (NWT) comprises a Phanerozoic sedimentary basin that lies between the western margin of the Slave craton and the Cordillera. Although the region is considerably outside the bounds of the exposed Slave craton, both LITHOPROBE and more recent regional-scale surface wave studies (e.g., Priestley and McKenzie, 2006) indicate the likely presence of lithospheric mantle extending into the diamond stability field.

Recent work conducted by Olivut Resources Ltd. led to the discovery of 29 kimberlites in the CMV. However, the indicator mineral chemistry of discovered kimberlites does not appear to be a good match ([www.olivut.ca](http://www.olivut.ca)) with those during regional till and stream sediment sampling by the Geologic Survey of Canada (GSC) and Northwest Territories Geologic Survey (NTGS) in August 2003 and July 2005. We present new geochemical data on the regional indicator minerals with the aim of obtaining geotherm and depth of mantle sampling constraints on those indicator minerals discovered to date. A statistical evaluation of the data will compare the similarities to indicator mineral chemistry with parts of the Slave craton to evaluate whether the CMV indicators may ultimately be derived from that region.

In total 3600 kimberlite indicator mineral grains were picked from the 0.25-2.0 mm size fractions. Peridotitic garnet grains dominate (46%), followed by magnesium ilmenite (26%), with decreasing individual

proportions >15% of chromite, low-chrome diopside, olivine, chrome-diopside and eclogitic garnet. A sub-sample of these grains (3143) were analysed by EPMA. Garnet grains classify (after Grütter et al., 2004) as 1015 (62.1%) G9, 270 (16.5%) G11, 113 (6.9%) G10, 103 (6.3%) G12, 57 (3.5%) G1, 46 (2.8%) G10D, and the remaining 31 (1.9%) as G0, G3, G3D, G4, and G5. A sub-set of garnet grains (~700) were selected for LA-ICP-MS trace element analysis. Of the grains selected 74% G9, 14% G10 (and G10D), and 8% G11, with only 4% G12 and G0 (Grütter et al., 2004). Nickel concentrations from these grains range from 2.6-168.2 ppm, with the majority (>80%) between 20-100 ppm, yielding TNi (Canil, 1999) values ranging from 643-1348°C, with the majority between ~1000-1200°C. Using a central Slave craton geothermal gradient (Hasterok and Chapman, 2011), equilibration pressures for these garnet grains range from 20-80 kbars with the majority between 40-60 kbars (120-185 km). Preliminary analysis has 581 (81%) of the erupted peridotitic mantle garnet grains plotting within the diamond stability field (Kennedy and Kennedy, 1976).

Of the 128 clinopyroxene grains analysed, only a few represent garnet peridotite (Iherzolite) facies KIM clinopyroxene grains following compositional screening. Thermobarometry of these grains (Nimis and Taylor, 2000), assuming they were all derived from the same lithospheric section, yields P-T arrays identical to the central Slave geotherm that was 220 km thick at the time of eruption. These results are encouraging for diamond exploration.

We thank Overburden Drilling Management Ltd. for grain picking and recovery of the small diamond, SGS Lakefield Research for

mounting grains, and the GSC for probing of the grains.

## **MORPHOLOGY AND SEDIMENTARY ARCHITECTURE OF THE EXETER LAKE ESKER IN THE LAC DE GRAS AREA, NORTHWEST TERRITORIES**

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During summer 2015, a large integrated dataset (ground-penetrating radar, grain size and drill holes) was collected from the Exeter Lake esker, Lac de Gras area, Northwest Territories. Along with a 45 by 70 km industry-donated LIDAR dataset, these data are being analyzed to investigate the processes behind esker deposition. The Exeter Lake Esker is the longest in Canada (over 700 km) and Kimberlite indicator mineral (KIM) samples from this esker led to the discovery of the Lac de Gras kimberlite field in the 1990s. Current knowledge of esker genesis is limited, and detailed studies of eskers on the Canadian Shield are sparse. Advancing the understanding of esker deposition with a focus on Canadian Shield examples could help constrain estimations of sediment provenance and transport distance, having important implications for mineral exploration.

Results are preliminary, but some meaningful interpretations can be made. For this study, the components of the esker have been broken down into three main morphological types: (Type I) Narrow ridges (15-30 m high, 40-100 m wide), characterized by steep sides (23-27 degrees) and narrow peaks, with primarily cobble and

boulder sized surficial sediments; (Type II) broad ridges, similar to the Type I ridges in height, but much less peaked and generally wider (60-150 m) with flat to gently rounded tops and surficial material consisting of fine sand to cobbles, the former locally scattered sparsely with angular boulders; (Type III) “Pads”, which are large, wide (100-300 m), flat-topped elements, with steep to gently sloping (25-15 degrees) sides, commonly covered in sand to cobbles and typically flanking or detached from the main ridge. Evidence of landform collapse in all esker elements, likely due to melting of subsurface ice, can be readily observed in the LIDAR. Without the LiDAR, such an interpretation is not obvious: from the ground, the helicopter, and in standard air photos, many of these features commonly appear to be complexes of Type I or II ridges. Ground Penetrating Radar (GPR) was used to image the shallow subsurface (6-30 m) of the esker, and the data obtained were of very high quality. Esker material is readily distinguished from adjacent till, and distinct radar facies are found in each aforementioned esker element. Abundant hyperbolas and a lack of any smooth, parallel reflections in the Type I ridges indicates that the surficial boulder material is likely massive and continuous to the base of the esker. GPR profiles across Type II elements indicate gently dipping (10-18 degrees) inclined reflections, and dispersed hyperbolas, indicating relatively homogeneous, well bedded clinoforms in sandy material, with sparse cobble sized clasts. Type III Pad elements often show reflections consistent with a 1-1.5 m thick package of gravel and cobble size clasts at the surface, with a relatively abrupt transition to clinoforms and well bedded sandy material, similar to type II. These interpretations were aided by observations from augured drill holes. The focus for the remainder of this research is to continue to

integrate GPR, LIDAR and surficial observations to determine the depositional history of the esker.

## **DEVONIAN AND CRETACEOUS SHALE RESOURCE SYSTEMS, PEEL AND MACKENZIE PLAINS, NORTHWEST TERRITORIES**

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Organic-rich, marine shale deposits of Devonian and Cretaceous age are extensive within the Peel Plain and Mackenzie Plain hydrocarbon exploration areas of the mainland Northwest Territories. Shale resource systems contain mudrocks of variable fine-grained lithologies that act as both source and reservoir rock and meet the following criteria: good to excellent total organic carbon (TOC), thermal maturity within the oil or gas windows, brittle rock fabric, and interbedding with organic-lean lithofacies. These criteria are being evaluated within prospective shale resource plays in the Devonian Horn River Group (Canol and Hare Indian formations), Devonian Imperial Formation, and Cretaceous Slater River Formation. Refinement of the tectono-stratigraphic and depositional framework for these potential shale plays is also a priority.

This study, initiated by the Northwest Territories Geological Survey Petroleum Group, is focused on the evaluation of source rocks for both shale resource play potential and source potential for conventional petroleum plays. The goal is to improve the source rock characterization



dataset from subsurface wells in both Mackenzie and Peel Plains, and integrate these results with analyses from outcrop sections that serve as analogs. Characterization includes Rock-Eval/TOC, thermal maturation, inorganic litho-geochemistry, and mineralogical analyses.

The Canol Formation is a known source rock for the conventional oil reservoir at Norman Wells, NWT. Unconventional oil resources from Devonian shale within Mackenzie Corridor are estimated by the National Energy Board to contain 145 billion barrels of oil-in-place within the Canol Formation and 46 billion barrels of oil-in-place within the Bluefish Member (Hare Indian Formation). Thermal maturation data suggests Canol Formation strata are within the oil window throughout much of Mackenzie Plain, with excellent source rock potential (median >4wt% TOC from outcrops and subsurface analyses). Data is sparse within the Peel Plain, but new subsurface analyses indicate TOC values ranging from < 1wt% TOC to > 6wt% TOC, with an increasing maturity trend from east to west across the Plain. In the southern Mackenzie Plain, new subsurface reflectance analyses suggest the Canol Formation is over-mature, and less organic-rich (median 2.07wt%) compared to the central and northern part of the plain. The Canol Formation is characteristically silica-rich (60-90% SiO<sub>2</sub>).

Rock-Eval/TOC data from field samples of the Imperial Formation suggest it has good to very good source rock potential (up to 3.3wt% TOC) and is within the oil window south of Peel Plain. Rock-Eval/TOC analyses of the Cretaceous Slater River Formation in outcrop also indicate range of good to very good potential source rocks (up to 3.39wt% TOC). Despite low pyrolysis

Tmax values indicative of immaturity along the eastern edge of Mackenzie Plain, the Slater River Formation may be oil-prone due to high sulphur kerogens. Maturity trends and litho-geochemistry for both of these units, in addition to a better understanding of the Canol Formation play within Peel Plain, require more analyses as this project proceeds.

## **FINE-SCALE VARIABILITY IN PERMAFROST TERRAIN AND ITS CONTROL ON GROUND TEMPERATURE**

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Surface and subsurface conditions in permafrost terrain control ground temperature. These conditions vary both spatially and temporally. As means to measure permafrost temperature at depth, boreholes are drilled and instrumented. Due to heterogeneity of terrain in permafrost regions, it can be difficult to determine exactly how a given condition influences the temperature in the ground. Spatial variation occurs at different length scales, and when one temperature series represents a large area with undetermined variability, it becomes hard to pinpoint the relation between surface conditions and their control on ground temperature. Subsequently, when one data series is applied to a large area it introduces a random component of whether that one sample truly represents the population mean. This becomes problematic when that data is used describe and predict temperature change over time. This research aims to describe and understand the local variability at a fine scale in order to better quantify that random component. Here,



## 2015 NORTHWEST TERRITORIES PETROLEUM RESOURCES DIVISION & PETROLEUM INDUSTRY ACTIVITY OVERVIEW

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“fine scale” is defined by a 15 m by 15 m area. The method is to select four points within a site that are representative of the variation found there. One data logger is installed 10 cm below the surface at each point. By doing so, regional variables such as latitude, incoming solar radiation, wind, and precipitation are being applied to all four loggers at the site. Any difference in temperature between the four loggers at a site can be attributed more specifically to the conditions at the surface and subsurface above them. That difference will inform on how representative one temperature measurement can be for a heterogeneous site.

This method was applied to 43 sites in the Lac de Gras region of the Northwest Territories. The sites are divided into three terrain types: organic, block field, and bedrock. Sites are located on hilltops, hill slopes, eskers, and valleys. The range in terrain type allows for the local variability to be analyzed within a site and then compared to a site of the same, or different, terrain type to determine regional variability. The surface conditions measured and documented were local topography, vegetation (type, height, and leaf area index), along with surficial permafrost landforms. The subsurface conditions measured and documented were soil properties, moisture content, and organic layer thickness. An initial analysis based on one month of ground temperature data has shown temperature variation within fine-scale sites, as well as between sites of differing terrain types.

A brief breakdown of the Government of Northwest Territories' post Devolution oil and gas administration begins with the Petroleum Resources Division, part of the Department of Industry, Tourism and Investment. We are guided by the Oil and Gas Operations Act and the Petroleum Resource Act along with several sets of regulations. The associated offices that have a role to play in oil and gas activities are the 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 (MVPPPO).

PRD is currently working on an Oil and Gas Strategy. It will include the key elements that are required for a sustainable oil and gas sector in the territory that will enhance transportation infrastructure, community education and outreach, marketing and promotion, resource characterization and other factors that have constrained development of NWT's conventional and unconventional petroleum resources. A public engagement report, Pathways to Petroleum Development, included the information and input received from industry, as well as NWT residents and was recently tabled in the Legislative Assembly and is currently available on our website. PRD was also involved in the development

of the hydraulic fracturing regulations. We visited 12 communities in the NWT and held public engagement meetings. These regulations, though not yet finalized, are on hold until the establishment of the next government.

During 2015, production operations were focused mostly in Norman Wells, a small amount from the Ikhil well north of Inuvik and some in the Cameron Hills region.

In 2015 the National Energy Board and the Northwest Territories Geological Survey released a report assessing the unconventional petroleum resources in the Canol and Bluefish shales of the Central Mackenzie Valley. The expected in place was calculated at a total of 191 billion barrels, with 144.8 in and Canol and 46.3 in the Bluefish. Although no one yet has the data to estimate what percentage would be recoverable, vital to ever developing these deposits is the construction of the Mackenzie Valley Highway.

The Imperial Oil Joint Venture in the Beaufort Sea submitted a letter in June 2015 to the NEB and EIRB delaying any further work on their planned exploratory drilling project. IOL cited not enough time to properly prepare for the project, given their two leases expire in 2019 and 2020 respectively. Chevron submitted a letter earlier in the year delaying their Beaufort sea drilling project due primarily to economic considerations. Imperial has also submitted a request to the Federal Dept. of Aboriginal Affairs for extensions to their two exploration licences in the Beaufort.

## **RECONSTRUCTING EARLY TO MID-HOLOCENE LANDSCAPE EVOLUTION IN THE CENTRAL NORTHWEST TERRITORIES, CANADA: INSIGHTS FROM BIOLOGICAL PROXY DATA**

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In the Great Slave Lowlands of the central Northwest Territories, clay-rich sediments from glacial Lake McConnell are widespread and commonly overlain by silty and sandy sediments derived from ancestral Great Slave Lake and its inflow streams. Despite the regional significance of this large proglacial lake, limited palaeoecological work has been undertaken, and few studies extend back to the early postglacial period. In this paper, we present palynological, chironomid and diatom data from a series of peatland and lake sites located within and beyond the former glacial lake limits to shed light on the character of landscape evolution after proglacial lake drainage and climate-vegetation interactions in the early to mid Holocene. Peat initiation at White Truck bog and Cameron River bog in the North Slave region began at 7738-

7943 cal BP and 6990 – 7134 cal BP, respectively. Birch shrubland dominated the landscape during this time. Both peatland records reveal evidence of a fen-bog transition. The palaeoecological record from the two sites also display a number of differences, which reflect local variations in hydrological conditions and fire histories. The chironomid record from Matthew's Lake (ca. 200 km beyond the glacial lake limits) shows that oligotrophic and cold stenothermic taxa prevailed during the earliest phases of clastic sediment deposition with a high species diversity. A transition from fine grained clay to gyttja is dated to 8423-8585 cal BP and correlates with a decline in cold-adapted species. This work provides new insights into the timing and character of vegetation colonisation and northwards migration of forests as the climate warmed during the early post-glacial period.

## GIANT MINE REMEDIATION PROJECT REGULATORY CONTEXT

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Following the discovery of gold in the Yellowknife, Northwest Territories area, Giant Mine officially opened in 1948. After the mine closed in 2004 the care and control of the mine fell to the Department of Aboriginal Affairs and Northern Development Canada (AANDC), and attention focused on the environmental issues left behind, including the arsenic trioxide stored in underground chambers. The Giant Mine Remediation Project was created in 2005 with the overall goal to protect human health and safety, and the

environment.

The site lies within the Mackenzie Valley watershed, and is regulated by the Mackenzie Valley Resource Management Act (MVRMA). The MVRMA is federal legislation aimed at creating an integrated system for protecting the lands and waters within the Mackenzie Valley watershed. Since the site is under the care and custodianship of AANDC, it is also subject to other federal acts, such as the Canadian Environmental Protection Act, the Fisheries Act and the Migratory Birds Convention Act, among others. It is also situated within the municipal boundaries of the City of Yellowknife, and so is impacted by the City's bylaws and permitting requirements.

The Project has recently completed a seven year Environmental Assessment process under the MVRMA, which resulted in 26 legally binding measures being incorporated into the project scope. The Project Team is now proceeding with a clearly defined list of requirements established through the process for the project, but faces many challenges going forward, including technical considerations, regulatory & jurisdictional constraints, consultation & engagement requirements, and resource pressures. A number of the measures will need to be completed, or substantially completed, prior to submitting an updated water licence application for the project. Specific components of the project require stakeholder input before being included in the updated consolidated project description, and the measures require the creation of an independent oversight body to provide input into options analysis as well as oversee research into a long-term solution for the arsenic trioxide dust.

In addition to the requirements from the EA, the project will require a land use permit

from the MVLWB for specific project activities, and various development and demolition permits from the City of Yellowknife. Various other permits or authorizations may be required during the life of the project, such as fisheries authorizations, research permits (wildlife, scientific, medical), archaeology permits and migratory bird permits.

This presentation will describe the consultation and engagement requirements that the project must follow in order to obtain the necessary permits, and discuss the impacts the processes and measures will have on the overall project schedule.

## **THE GAHCHO KUÉ MINE DEWATERING EXPERIENCE, WINTER 2014-2015**

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Construction of the De Beers Gahcho Kué Mine required that a portion of Kennady Lake be dewatered to provide access to kimberlite pipes on the lakebed. The Construction Water Management Plan considered an initial dewatering volume of approximately 18.7 Mm<sup>3</sup>, to be discharged to two downstream waterbodies (Lake N11 and Kennady Lake Area 8). This dewatering was originally planned to occur during the open water season, after the spring freshet peak.

The project received its Type A Water Licence from the Mackenzie Valley Land and Water Board on September 24, 2014, and before that date it had become apparent that winter dewatering would be required to prevent a significant delay in the project

development. Potential adverse impacts related to winter dewatering were identified and were primarily related to aufeis development. Aufeis is defined as an ice deposit, formed by vertical growth of layers as thin flows of water are exposed to freezing temperatures. These may have adverse effects on erosion, fish and fish habitat.

Action levels for winter dewatering were developed, based on site-specific hydrological characteristics, and were included in the Aquatic Effects Monitoring Program for the Mine. This allowed field measurements to be compared to action levels during the dewatering program. Field measurements included telemetry to monitor lake hydrostatic water surface elevations, as well as periodic visits to the receiving lake outlets and downstream areas to examine ice and flow conditions.

Winter dewatering commenced on December 20, 2014, with pumping to Kennady Lake Area 8. Pumping was suspended on January 4, 2015, as the action level for that location was approached. Approximately 779,000 m<sup>3</sup> of water was released over 16 days. Dewatering discharges were then pumped to Lake N11, with pumping commencing on February 1, 2015 and continuing through the winter period, as the action level for that location was not exceeded. Over the 103 day period through May 14, 2015, approximately 6,021,000 m<sup>3</sup> of water was released.

A total of 6,800,000 m<sup>3</sup> of water was discharged from Kennady Lake over the winter dewatering period, or about 36% of the planned initial dewatering volume. Winter and subsequent open-water season reconnaissance did not identify any adverse effects due to winter dewatering.

This presentation will discuss winter dewatering risks, action level development, field program observations, and factors contributing to the overall success of the program.

## **YELLOWKNIFE CITY GOLD PROJECT-EXPLORATION UPDATE AND MIP RESEARCH RESULTS**

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TerraX continued exploring the Yellowknife City Gold Project (YCGP) in 2015. The YCGP is underlain by the Yellowknife Greenstone Belt, host to the past-producing, high-grade Con and Giant gold deposits. TerraX continued drilling their advanced Crestaurum and Barney Shear targets, discovered a new style of mineralization, added to their land package, and continued prospecting and mapping activities.

TerraX staked the southern extension of the Yellowknife Greenstone Belt, adjoining the Con leases, bringing their total land position to 116 sq km, encompassing 23 strike km of the greenstone belt. Preliminary reconnaissance yielded samples up to 94.9 g/t Au on this new property. Drilling at Crestaurum produced intersections such as 7.0 m @ 10.23 g/t Au in the South Shoot; at Barney the best drill intersection in 2015 was 14.09 m @ 2.96 g/t Au. Highlights of the surface exploration program included samples up to 108 g/t Au on a new shear near the Pinto Vein, a 20.6 g/t Au sample in a new area called JED West, and a chip sample of 2 m @ 21.4 g/t Au on Shear 17 proximal to the Ryan Lake pluton. Numerous gold-molybdenum veins were sampled near this pluton. Approximately ten targets were advanced to drill-ready stage.

Geological mapping identified the >500 m wide, north-northeast trending Barney Deformation Corridor, featuring several areas of extensive sericite alteration and significant sulphide concentration. Within this corridor, channel samples from the Hebert-Brent showing returned 11.0 m @ 7.55 g/t Au and 6.0 m @ 10.26 g/t Au. Mineralization is replacement style, and unusually for the Yellowknife gold camp, there is a noticeable lack of quartz veining.

Two biogeochemical orientation surveys were conducted over the Crestaurum structure and a test production survey was conducted over the Barney Shear. Four vegetation types were sampled: black spruce, mountain alder, juniper and Labrador Tea. Samples were collected at 10 m intervals on 25 m (orientation) to 50 m (production) spaced lines. The vegetation types had different background levels of metals, but each type had anomalous concentrations of gold, arsenic and antimony proximal to known surface mineralization. The approach is concluded to have potential as an exploration tool.

The chemical signature of alteration was examined with a field gamma ray spectrometer. In particular, the radio-assayed thorium/potassium ratios were determined across mineralized structures. Such structures commonly have a detectable potassium enrichment within and immediately adjacent (5 m) to them. The Barney Shear and Gold Lake areas were good examples of detectable alteration using the spectrometer. In theory, this means that alteration signatures might be detectable in airborne radiometric data. Field checking of actual airborne radiometric anomalies produced limited success.

Hydrothermal alteration mineralogy was



examined by means of a Terraspec instrument. 544 mineralogical analyses from drill core and surface samples were collected. Preliminary examination of this data suggests that there is a general tendency for chlorite spatially associated with mineralization to be more iron rich than chlorite occurring further from mineralization. It is not yet clear whether this information can be used as an exploration technique.

## **YELLOWKNIFE CITY GOLD PROJECT- UPDATE ON DRILLING AND NEW DISCOVERY**

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The main focus for TerraX in 2015 was the Core Gold Area of the Yellowknife City gold Project, which extends over a 4km x 2km area in the central portion of the property. During 2014-2015, 114 NQ drill holes totaling 18,137 metres were completed. The majority of this drilling was on the advanced Crestaurum Shear Zone (86 DDH totaling 11,227m) and Barney Shear Zone (22 DDH totaling 5,957m) targets.

Work on the Crestaurum Shear Zone has expanded the historic shoots, known as the south, central and north shoots. The dominant mineralization style consists of laminated quartz-ankerite veins that are hosted in sulphide bearing interflow sediments, flow top breccia's and hyaloclastite units at the contact of gabbro dykes and massive to pillowed mafic volcanic flows. The gold mineralized quartz-ankerite veins are typically folded and boudinaged and contain arsenopyrite, stibnite, galena, sphalerite and locally

visible gold. The alteration zonation observed changes from distal calcite to chlorite to proximal sericite. Within this zone some of the more significant drill intersections are:

- 33.60 g/t Au over 2.85 m (hole TNB14-019)
- 10.32 g/t Au over 7.00 m (hole TCR15-003)

Work on the Barney Shear Zone has expanded the historic zone. There are multiple generations of gold mineralized laminated to colloform quartz +/- ankerite veins. The two dominant mineralization styles are gold-arsenopyrite dominant laminated veins and silver-lead with lesser gold dominated bull to colloform veins. Some of the more significant drill intersections are:

- 0.28 g/t Au, 86.70 g/t Ag and 7.73% Pb over 2.65 m (hole TNB14-010)
- 3.62 g/t Au, 3.00 g/t Ag and 0.02% Pb over 4.00 m (hole TNB14-010)

A third style of gold mineralization within the Barney Shear Zone is related to arsenopyrite replacement of pyrite in semi-massive pyrite zones. Within this zone the most significant drill intersection is 18.40 g/t Au over 5.16 m (hole NB95-16W1). The host rocks to the mineralization are shear zones at the contact between gabbro dykes and massive to pillowed mafic volcanic flows or quartz-feldspar porphyry dykes.

Geological mapping completed during the summer of 2015 identified several areas of mappable and locally extensive sericite alteration within the >500 m wide, north-northeast trending Barney Deformation Corridor. This work resulted in the discovery of a new surface showing, the Hebert-Brent Zone. This zone contains

replacement style mineralization consisting of semi-massive arsenopyrite and pyrite with only minor quartz veining associated with the anomalous gold. Other associated metals in proximity to the higher grade gold are antimony, lead and zinc. Channel samples from the Hebert-Brent showing returned 11.0 m @ 7.55 g/t Au and 6.0 m @ 10.26 g/t Au. The host rocks to the mineralization are shear zones at the contact between gabbro dykes, a sequence of bleached pillowed mafic volcanic flows, felsic pyroclastic rocks, interbedded chert/sulphide units and quartz and feldspar porphyry dykes. Six drill holes totaling 953 m were completed on this zone with results pending.

## **POST-CALVING AND SUMMER HABITAT SELECTION BY A DECLINING CARIBOU HERD IN THE CENTRAL CANADIAN ARCTIC: APPLICATIONS FOR CUMULATIVE EFFECTS MANAGEMENT AND CONSERVATION.**

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Barren-ground caribou (*Rangifer tarandus groenlandicus*) are a biologically and culturally important species in the Arctic. Caribou not only sustain wild predator populations such as wolves, grizzly bear and wolverine, but also provide a critical resource for human populations living in the North, particularly Aboriginal communities. Hunting, disease, and environmental variability can all affect caribou numbers, and the effects from industrial activities occurring within the species range are monitored for management of caribou.

The Bathurst caribou herd winters below the

treeline and migrate to calving grounds currently to the west of Bathurst Inlet, the herd's namesake. The Bathurst caribou herd has experienced significant declines since the mid 1980's, to around 16,000 animals currently. These population trends have been attributed to declining calf survival, and concomitant declines in adult female fecundity, and low over-winter survival. While the decline in caribou numbers may be a consequence of natural population cycles, current low numbers make the populations vulnerable to human harvest, disturbance, disease, and weather events. Caribou vary in their response to disturbances based on the time of year and age of calves. Caribou may be sensitive to population-level effects during calving and post-calving when calves are most susceptible to predation and disturbance.

Recent evidence suggests that over-winter survival of calves may be related to conditions on the summer range. Inadequate leaf biomass, late start date and early end date of green leaf biomass, and poor quality of leaf biomass in the summer range are generally believed to be detrimental to caribou growth and pregnancy rate during the summer-fall period and calf:cow ratio in the next year. Understanding the relative contributions of natural and anthropogenic factors to population level changes is the goal of cumulative effects assessment, and fundamental to developing sound management practices to promote the long-term sustainability of the Bathurst herd.

Resource Selection Functions are increasingly being used to provide information on essential resources needed to manage and conserve rare, threatened, and endangered species in complex socio-environmental landscapes. RSFs provide an objective and explanatory framework to assess habitat selection and relative habitat

quality at multiple scales and across individuals and populations. We present results from RSF modeling for the Bathurst herd using GPS collar data collected between 2004 and 2011. The modeling effort focused on the post-calving and summer ranges as these periods are when caribou calves may be most vulnerable, and conditions on these ranges may determine over-wintering success and recruitment. We discuss these results in the context of cumulative effects management, and explore paths forward to understanding potential mechanisms that underly the declining population trend.

## **GEOCHEMICAL INSIGHTS INTO THE ORIGIN OF UNION ISLAND GROUP MAFIC MAGMATISM, EAST ARM BASIN, GREAT SLAVE LAKE**

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The Paleoproterozoic Union Island Group (UIG) is a package of dominantly mafic volcanic and subordinant carbonate/shale sedimentary successions in the East Arm basin and is one of the earliest post-Archean successions emplaced on the southeastern margin of the Slave craton. New field observations indicate that the UIG rests unconformably on Archean basement, challenging previous stratigraphic interpretations in which the Wilson Island Group demarcated the base of the East Arm basin. The UIG therefore is a key stratigraphic unit in understanding the origin of the East Arm basin. We present new field

observations and results from a whole-rock geochemical study of volcanic and intrusive mafic rocks of the UIG. Two stratigraphically and geochemically distinct volcanic units are recognized within the Union Island Group: an alkaline to subalkaline basaltic lower assemblage with associated gabbroic feeder sills and dikes, and a subalkaline basaltic to andesitic upper assemblage. The lower assemblage is geochemically more variable, characterized by high TiO<sub>2</sub> (2.2–3.4 wt%) and low Cr (<60 ppm). In contrast, the upper assemblage has low TiO<sub>2</sub> (1.6–1.7 wt%) and high Cr (280–330 ppm), with a significant negative Nb-Ta anomaly. Both assemblages show LREE-enriched profiles, with the lower assemblage being more fractionated (average (La/Lu)<sub>N</sub>=7.6 compared to 4.8). Two geochemical profiles through basalts of the lower assemblage reveal that successive lava flows are derived from a common magma reservoir undergoing fractional crystallization. The restricted range of REE enrichment in the upper assemblage basalts indicates that they were derived from a distinct magma batch that has undergone limited fractional crystallization.

High Nb contents (~20–60 ppm), low Th/Nb ratios (<0.2), and a within plate basalt signature in the lower volcanic assemblage is consistent with a mantle plume origin with minimal crustal contamination. The upper assemblage has lower incompatible element abundances and a pronounced primitive mantle normalized negative Nb-Ta anomaly. The origin of the negative Nb-Ta anomaly remains to be elucidated. We recognize the need to test our interpretations further with tracer isotope study and U-Pb geochronology.

## DIAMOND FORMATION IN EARTH'S MANTLE

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Studies of mineral inclusions in diamond have conclusively established that the principal diamond substrates in Earth's mantle are peridotitic (about 2/3) and eclogitic (about 1/3) domains located at 140-200 km depth in the subcratonic lithosphere. There, the formation of the dominant harzburgitic diamond association generally occurred under subsolidus (melt-absent) conditions. In eclogitic and lherzolitic substrates, however, diamond grew in the presence of a melt, with relatively rare exceptions relating to formation from strongly reducing fluids or at relatively low pressure (<50 kbar) and temperature (<1050°C).

Complex internal growth structures indicate that in many instances, diamond formation did not occur in a single short lived event. The observed close agreement of radiometric ages involving different isotope systems and inclusion minerals for diamonds from individual occurrences, however, cannot be coincidental and implies that the temporal extent of individual diamond growth events is contained within the uncertainty of the age dates. Diamond formed through most of Earth's history, from the Paleoproterozoic to at least the Mesozoic. Diamond forming episodes occur on regional to global scales in response to tectonothermal events such as suturing, subduction and plume impact. Individual diamond forming episodes may be associated with particular substrates, with harzburgitic paragenesis diamonds generally yielding Paleoproterozoic (3.6-3.2 Ga) ages and lherzolitic paragenesis diamonds forming mostly in the Paleoproterozoic at ~2 Ga.

Peridotitic diamond growth, however, continued through Earth's history, with the youngest age date being ~90 Ma. Formation of diamonds hosted by eclogite is documented from the Mesoarchean to the Neoproterozoic (2.9 and 0.6 Ga) and may well continue up to the present. Multiple lines of evidence suggest that formation of fibrous diamonds and diamond coats often is penecontemporaneous to kimberlite magmatism and hence, for the Central Slave, may even extent into the Tertiary.

When it comes to the actual process(es) driving the precipitation of diamond, our knowledge is much less complete. Diamond grows during the infiltration of carbon-bearing fluids or melts into a suitable substrate. But what exactly is the diamond forming reaction that occurs there? The conventional view that redox reactions between percolating fluids/melts and wall rocks are nature's diamond recipe is inconsistent with both the low redox capacity of lithospheric mantle and the occurrence of large diamonds. Based on thermodynamic modeling, we instead propose that isochemical cooling or ascent of carbon-bearing fluids is a key mechanism of diamond formation. It operates particularly efficiently in chemically depleted mantle rocks (harzburgite), where a high melting temperature precludes dilution of the infiltrating fluid (see above), thereby explaining the long observed close association between diamond and harzburgitic garnet.

## **TEHERY-WAGER GEOSCIENCE PROJECT: FINDINGS FROM THE 2015 BEDROCK MAPPING CAMPAIGN**

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The Tehery-Wager Geoscience Project is a four-year initiative conducted by the Geological Survey of Canada and the Canada-Nunavut Geoscience Office. The project aims to gather new geoscience information to create modern bedrock and surficial geology maps, evaluate the economic potential in the area, and characterize the tectonic, magmatic, depositional, and metamorphic history of the bedrock units therein.

The first of two field seasons of regional bedrock geology mapping was conducted in the Tehery-Wager region, north of Chesterfield Inlet, Nunavut, this past summer and focused on a better documentation and characterization of rock types and features across the eastern part of the study area. This area is believed to comprise rocks of the Rae Craton, and includes the Wager Shear Zone, the granulite-facies Daly Bay Complex, and possibly part of the suture between the Rae and Hearne cratons known as the Snowbird Tectonic Zone. Major rock units observed include Archean tonalite to syenogranite gneiss, granitic gneiss to K-feldspar porphyritic monzogranite (in part correlative with the ca. 2.6 Ga Snow Island Suite), presumed Proterozoic supracrustal rocks, undeformed monzogranite to syenogranite

(likely correlative with the 1.85–1.81 Ga Hudson Suite), and roughly coeval ultrapotassic clinopyroxenite to syenite intrusions.

Most lithological units throughout the study area maintain a pervasive shallowly- to steeply-dipping mineral fabric, referred to as Smain in the field. Several areas with mylonitic to strongly lineated fabrics were identified well-away from known high-strain zones such as the Wager shear zone and the Daly Bay complex. Shallowly to moderately, NE-SW-plunging mineral and stretching lineations are locally present. Their geometry is consistent with shallow- to moderately-plunging NE-SW-trending fold hinges that define the main regional map pattern. The relationships between deformation fabrics and metamorphic mineral assemblages documented across the area suggest that the development of Smain was contemporaneous with upper amphibolite- to granulite-facies metamorphism. Regional, retrograde metamorphism to amphibolite-facies conditions are interpreted based on ubiquitous plagioclase+biotite rims around garnet porphyroblasts.

Targeted sampling to determine economic potential in the area was conducted on gossanous, presumed Proterozoic supracrustal rocks adjacent to till samples that were collected in 2012 and had returned elevated metal concentrations. Samples were also collected from newly identified gossanous horizons, mafic and ultramafic layers in these supracrustal rocks, and unusually low-grade metasedimentary rocks at the margin of the Daly Bay complex to evaluate their metal content. Ultrapotassic intrusive rocks were sampled to quantify their rare earth element concentrations.



## **A COMMUNITY STEWARDSHIP OPTION FOR FISHERIES PRODUCTIVITY OFFSETTING IN THE NORTHWEST TERRITORIES**

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The availability of measures to offset negative impacts of remote mining developments on fisheries resources in the Canadian Arctic is limited, and options near such development generally have minimal benefits to traditional users of fish. We present a community stewardship option to improve migration conditions for spawning Northern Pike in a small creek near Lutsel K'e, NT, for Dominion Diamond's Lynx Project. Baseline data identified a migration of Northern Pike from Great Slave Lake that encounter numerous barriers that can result in stranding, direct mortality, and impede passage to a network of ponds used for spawning and rearing. A remediation plan based on low-impact construction methods was identified through engagement with the local community as an effective method for improving access to upstream ponds and reducing fish mortality. The plan includes channel remediation at identified blockages and the modification of the main pond outlet to sustain flows through the migration period. We predict that complete remediation of the creek will add at least 500 adults to the fishery, or greater than 700 kg of new harvestable biomass over a 10-year period. Furthermore, we expect that fish production gains will magnify over time

when recruits return as adults and may greatly exceed production losses from the drawdown of a small, low-productivity lake. This offsetting option relies on community engagement and will provide local community members with the capacity to contribute to the successful implementation of the project over the long-term.

## **MINERAL DEVELOPMENT STRATEGY IMPLEMENTATION PROGRESS REPORT**

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The Government of the Northwest Territories (GNWT) developed the NWT Mineral Development Strategy (MDS) to build a foundation from which it might encourage mineral exploration and mine development, while protecting the environment, respecting aboriginal and northern residents and promoting a sustainable economy. The Strategy guides the NWT in balancing multiple priorities and links decision making and planning tools that concern mineral exploration and mining across the NWT.

The MDS Implementation Plan, released in October 2014, commits the GNWT to fulfill objectives following the Devolution of the responsibility for lands and resources. Based on the five pillars of the MDS, the Implementation Plan laid out 28 action items to be worked on during the 2014-15 fiscal year. In October 2015 the 2014-15 Progress Report was released and details the activities completed, those in progress, and others that are in preparation to begin. This talk will summarize the progress to the end of October 2015.

## **GEOCHEMISTRY AND CARBON CONTENT OF PERMAFROST AND ACTIVE LAYERS IN TUNDRA LANDSCAPES OF LAC DE GRAS, NORTHWEST TERRITORIES, N.W.T**

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Permafrost and active layer samples from 25 sites were collected to examine the vertical and spatial distribution of cation concentrations and organic carbon from the Lac de Gras region, of the Northwest Territories, Canada. While studies from Mackenzie delta region and Herschel Island report that the active layer and near-surface permafrost are geochemically distinct, geochemistry of permafrost in the present study area is not well documented. Unlike previously studied regions, the Lac de Gras area is a bedrock-dominated environment with a thin, patchy veneer of glacially derived surficial soils. The main aim of this research is to describe the ionic characteristics of the active layer and permafrost in glacial sediments of the Lac de Gras area.

At the moment, one of the major gaps in literature related to permafrost geochemistry is the study of permafrost at depths of greater than a few metres below the surface. This is especially true for the tundra areas of the Slave Geological Province. Field observations from the northwestern Canada indicate that ground temperatures have increased in the upper 30 m of permafrost, by up to 2°C over the past 20 years.

Understanding the geochemistry of permafrost is important as it may influence the thermal and physical properties of frozen ground and may indicate the potential consequences on soil and water chemistry if it were to thaw.

In the present study, soil cores were extracted from depths up to 12 m using a heli-portable diamond-drilling core. A number of sites were sampled, including: peatlands, eskers, hilltops, hill slopes, highly vegetated surfaces, and earth hummocks and depressions in valleys to examine landscape-scale variability. All core samples were sectioned at 20 cm intervals, logged, and double-bagged in the field and returned to a laboratory in Yellowknife. In the laboratory, samples will be analyzed for gravimetric water content, excess ice content, electrical conductivity and major cations ( $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{K}^+$  and  $\text{Na}^+$ ). Sub-samples will be sent to Carleton University's permafrost research laboratory. These samples will be analyzed to estimate organic carbon content using loss on ignition method.

The study design, cores from multiple deposits and from aggrading and degrading surfaces, is novel and an important basis for the current research. It will help to characterize the vertical and spatial variability of ion and carbon concentrations in permafrost for the Lac de Gras region. Moreover, it will also provide data on geochemical and organic carbon content profiles to depths of up to 10 m. We anticipate contrasts in the geochemistry and organic matter content between the active layer and permafrost. We also anticipate that vertical profiles may vary between landscape types.

## **HOLOCENE FIRE REGIMES AND TREELINE MIGRATION RATES IN SUBARCTIC CANADA**

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Holocene climate change resulted in major vegetation reorganization in subarctic Canada near modern treeline but little is known of the effect of long-term climate change on boreal forest composition and fire regime below treeline. We present a vegetation and fire history from two sites within the modern boreal forest in the central Northwest Territories, Canada to provide new insight on subarctic vegetation response to Holocene climate dynamics and the dynamic role of fire in boreal ecosystems. Palynological analysis of sediments retrieved from Waite and Danny's lakes (informal) is used to reconstruct regional vegetation dynamics and boreal fire regimes. The longer Danny's Lake record documents treeline expansion beginning at ca. 7,430-7,220 cal yr BP. Integration of our new data with previous work shows that treeline expanded between ca. 4,050 cal. yr BP and ca. 3,840 cal yr BP at a rate of ca. 20 years/km in response to the 1-2°C increase

in temperature estimated for the Holocene Thermal Maximum. Forest fires were relatively frequent and severe during the early Holocene, with a mean (major) fire return interval of ca. <500 years before declining in frequency in response to cooler and wetter climate conditions associated with the Neoglacial. We document a trend of increasing fire frequency in the 20th century in response to recent warming that has almost reached conditions experienced during the Holocene Thermal Maximum. These dynamics south of modern treeline provide insight into factors creating heterogeneity in plant community responses to large-scale climate events in the subarctic and suggest that large scale reorganization of boreal vegetation and fire regime can be expected over the coming decades.

## **HYPERSPECTRAL IMAGERY: A NOVEL WAY TO ANALYZE KIMBERLITE INDICATOR MINERALS AND TO DETECT KIMBERLITE MICRO-FLOAT**

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The collection and analysis of kimberlite indicator minerals from heavy mineral concentrates is an integral part of the diamond exploration process. However, surficial sampling programs are often restricted by time-consuming mineral collection, processing, and analysis procedures. To facilitate the development of a technique that can simplify and accelerate the identification and classification of kimberlite indicator minerals, we explored the usage of hyperspectral imagery, which is based on the analysis of reflected radiation in the visible and infrared parts of the electromagnetic spectrum.

The investigation was focused on the identification of indicator garnets.

Hyperspectral imagery was collected directly from heavy mineral concentrates, and these images were de-noised and processed to isolate the spectral absorption features relating to mineral composition. These images were then analyzed to identify individual garnets. This portion of the analysis was complemented by the results of 1000+ high-resolution spectra collected from well-characterized crust- and mantle-derived garnets to ensure that the garnets in the heavy mineral concentrates were accurately identified.

Preliminary results indicate that garnets can be readily distinguished from other concentrate minerals using hyperspectral imagery, and that the garnets can also be compositionally classified. The compositional classification allows crust- and mantle-derived garnets to be distinguished accurately, while providing concentration information about certain transition elements, like chromium and titanium.

In addition to the garnet analysis, hyperspectral imagery was also used to identify millimeter-sized fragments of kimberlite (kimberlite micro-float) in heavy mineral concentrates and unprocessed sediment samples. Preliminary results indicate that kimberlite micro-float can be readily distinguished from other rock and mineral fragments due to its distinct spectrum. Pending additional testing, analytical techniques using hyperspectral imagery may serve as an alternative to the costly and time-consuming indicator mineral identification methods currently being used.

## **CONTAMINATION FROM GOLD MINING REORGANIZES MULTIPLE TROPHIC LEVELS IN POCKET LAKE (YELLOWKNIFE, NT, CANADA)**

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Large quantities of arsenic were released from the roasting of arsenopyrite ore at Giant Mine during its operational history. We assessed the long-term ecological impacts of emissions on aquatic ecosystems using a spectrum of chemical and biological indicators preserved in a radiometrically-dated lake sediment core from Pocket Lake, a small lake at the edge of the mine lease boundary of Giant Mine, receiving emissions solely from airborne deposition. Sedimentary metal profiles unambiguously tracked the striking increases (~1700%) in arsenic concentrations coeval with the initiation of Giant Mine operations. Other contaminants, including mercury from gold extraction via amalgamation, also increased, along with antimony, lead, and polycyclic aromatic hydrocarbons. Synchronous changes in biological indicator assemblages from multiple aquatic trophic levels in both benthic and pelagic habitats occurred coincident with these incredibly high metal concentrations. At the peak of contamination, all Cladocera, a keystone group of primary consumers, as well as all planktonic diatoms, were functionally lost from the sediment record. No biological recovery has been inferred, despite



decreases in metal concentrations following emission reductions more than 50 years ago, and the cessation of all ore-roasting/processing activities in Yellowknife in 2004. These results show the extent of contamination from gold mines in the NWT prior to regulatory intervention, and show that aquatic communities remain highly disturbed. The results from Pocket Lake provide a basis for interpreting other ecosystem changes as a result of contamination from Giant Mine using this paleoecotoxicological approach.

## **ECONOMIC ANALYSIS OF FRONTIER PROJECTS - THE NEED FOR REALISM**

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Oil and gas projects are routinely assessed using discounted cash flow analysis. Models developed for this purpose run the gamut from very simple to highly complex but in all cases depend on good calibration and proper collection of input parameters and of risks to provide reliable results. One can certainly use a simple success case approach with optimistic, high side values. In doing so, one creates the impression of a highly robust project. This can be very misleading and will create unrealistic expectations for both profitability and production – and in turn for the amount of wealth that is to be generated for possible sharing amongst various stakeholders.

Foremost amongst technical inputs are reserve calculations (porosity, pay thickness, water saturation, recovery efficiency and various losses). Use of unrepresentative high end values for these will sway the model. Likewise the production profiles selected may not be typical. Even when the project is up and running, its reliability is impacted by

weather, mechanical failure and seasonal effects. Using a model with full production 365 days a year is simply not realistic. Models also obviously need to include appropriate full cost midstream processing and transportation fees.

Both technical and non-technical risks are also critical as they can effectively kill a project. In a Frontier setting where calibration is poor, aspects such as reservoir risk, source risk and charge timing risk may lead to projects not being pursued - likewise for regulatory and related factors. These scenarios are portrayed in decision trees as multiple “off ramps”, each of which creates an economic burden.

As the time value of money has impacts on both costs and revenue streams, the chronology of a project is a critical factor. Models need to acknowledge that the gradual growth of the knowledge base and de-risking of the project create an expensive legacy of front end costs that can only be offset by strong ultimate project performance. Significant delays, if anticipated, can also throw an otherwise attractive project into the negative column and off the table.

It is incumbent upon governments to develop for their own use realistic models so that they can ensure that their level of take does not create an excessive burden on projects. The prize offered to industry must be adequate enough to carry the additional burdens of dry holes and the “off ramps”. Multiple scenarios can be created and economic regimes with adequate flexibility can be crafted. The added value of such models is that it enables governments to identify those factors, be they technical or otherwise, that are creating the downward pressures and to move to correct or at least to mitigate them.



This presentation will discuss many of the real world issues that affect economic analysis with the conclusion that it is essential for all to realize that we are generally dealing with ordinary geese and not the golden goose.

## **POLYMETALLIC NI-CO-AS-BI- AG-U VEINS WITH CO- PRECIPITATING BITUMEN AT COPPER PASS, SOUTHERN SLAVE PROVINCE, NORTHWEST TERRITORIES**

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Polymetallic veins have a distinctive history of precipitation in stages. Nickel-cobalt arsenides are ubiquitous in these veins while uraninite and other uranium minerals may be lacking due to absent stages. Similar polymetallic veins have been identified in few locations across North America and Europe. Historically economic varieties of these veins were mined in the Thunder Bay and Cobalt districts of Ontario and the Great Bear Lake region of Northwest Territories. The latter was mined for native silver and uraninite. Veins at Copper Pass, near Great Slave Lake, do not contain economic volumes of either resource but do host an interesting relationship between a subdued uraninite stage and solid bitumen.

Mineral and fluid inclusions are examined within vein quartz from Copper Pass. The uraninite stage, along with solid bitumen and Ni-Co arsenides, is hosted wholly within a specific layer of quartz growth. This study focuses on constraining the

mechanisms for the co-precipitation of these elements and characterizing their fluid source using various petrographic techniques.

Microscope-cathodoluminescence (CL) was used to identify growth patterns within individual quartz grains, which were subsequently analysed with secondary ion mass spectrometry (SIMS; University of Manitoba) to identify their oxygen isotope ratios. These ratios range from 3.9 to 25.3 ‰  $\delta^{18}\text{O}_{\text{quartz}}$  V-SMOW, increasing from core to rim with variations along specific growth zones. The uranium bearing zone in particular is consistently marked by a substantial outward increase in  $\delta^{18}\text{O}_{\text{quartz}}$ , implicating a major chemical shift during vein formation (e.g. fluid mixing). Calculation of  $\delta^{18}\text{O}_{\text{fluid}}$  using  $\delta^{18}\text{O}_{\text{quartz}}$  and fluid temperatures can be used to deduce the nature of source fluid mixing. Micro-thermometry of fluid inclusions has provided a range of salinity and homogenization temperatures for the trapped fluids, which were used to generate constant density isochores in P-T space. A minimum entrapment temperature of about 160°C was determined from this preliminary constraint. Further analysis of the inclusion phases, consideration of metamorphic conditions and bitumen maturity may add constraints to the P-T conditions of the precipitating fluids.

Compositional and textural features within the uranium-rich inclusion-bearing growth zone were identified using SEM and Raman spectrometry. SEM-EDS analysis showed different phases of chemical concentrations within these inclusions (e.g. U-rich, Ni-As-rich, and S-rich). Although distinct, these phases are often not associated with specific mineral compositions or grain boundaries. As a result they tend to blend together. Spectra collected using the Raman spectrometer indicates similar mixing of various vibrational signatures. Most spectra

do share common signatures from included bitumen, which were compared with spectra of hydrocarbons from different deposits. Hydrocarbons were also identified in rare examples of quartz fluid inclusions using both Raman spectrometry and UV light microscopy, which supports the idea that organics and uranium were transported in solution together during quartz precipitation. This study may provide insight into the role of organics in polymetallic deposits. Continued research will focus on determining the nature of fluid mixing that triggered the co-precipitation of these phases.

### **ABORIGINAL MINERAL DEVELOPMENT POLICIES AND STRATEGIES**

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In the face of competitive and volatile world markets and low commodity prices, many jurisdictions have advanced mineral development positions in the form of mining policies or strategies to provide clarity and put in place measures to attract and guide development. In a Canadian context, a number of provinces and territories have developed these policies with mixed results. In some cases, governments did not engage broadly in developing their positions and priorities, and Aboriginal Government or community perspectives were not necessarily reflected, leading to policies that did not recognize Aboriginal rights or integrate and align with existing or proposed land use plans.

In part as a response to this, a number of Aboriginal governments have recently developed, or are in the process of developing, their own mineral development policies or strategies. These policies seek to

provide clarity and put in place measures that attract exploration and mining while respecting the goals and requirements of communities, land claim agreements and existing land use plans.

This presentation will describe the current state of play in Aboriginal Government mineral development policies and strategies, discuss what has been learned, and how these learnings can be applied in the North.

### **LANDSCAPE IMPACTS OF HYDRAULIC FRACTURING DEVELOPMENT AND OPERATIONS ON SURFACE WATER AND WATERSHEDS**

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In this, one of five studies funded by Canadian Water Network (CWN), researchers from across Canada considered gaps in the knowledge related to hydraulic fracturing landscape impacts on surface water and watersheds. There is uncertainty about how complex social ecological landscape and watershed systems function. Through multi-disciplinary research, we considered both social and natural science frameworks. A theme that emerged was the variability in physical, social and regulatory infrastructure that exist across the country. Our team was struck by the complexity of the issues and by the need for better integration and coordination to address knowledge gaps. In particular the need to move away from silos and the polarization of social and natural science perspectives. There are opportunities for innovative approaches in bringing stakeholders together and there needs to be better appreciation and understanding of the differences between

economic and cultural land use and the potential for conflict. This requires transparency and accountability as well as the ability to measure, disclose and engage on cumulative effects.

## **HOW THE KWE BEH WORKING GROUP AND THE Tłıchǰ LAND USE PLAN CAN HELP YOUR FUTURE DEVELOPMENT ON Tłıchǰ LANDS**

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Formed in 2005 with the signing of the Tłıchǰ Agreement, Tłıchǰ Lands occupy an area of approximately 39,000 km<sup>2</sup> in the central Northwest Territories between Great Slave and Great Bear lakes. The Tłıchǰ Government has surface and sub-surface right on these lands. Once the agreement was signed the Chief Executive Council (CEC) decided to put a moratorium on Tłıchǰ lands, not allowing new development until the Land Use Plan was developed.

The Kwe Beh Working Group (KBWG) was established in 2010 to manage relationships to the mining and exploration companies that could impact the Tłıchǰ people in any shape or form. The KBWG is the first contact in the Tłıchǰ Government to manage files such as IBA's with industry, Roads, HR relations in mines, explorations camps etc. The KBWG is not a management authority, but rather gathers information and reports directly to the CEC.

The Land Use Plan came into effect the first of June 2013, with it the moratorium was lifted and Tłıchǰ Lands were open once again for industry. Tłıchǰ Lands are rich in resources and the Tłıchǰ Government want to strike a balance between sustainable development and ensuring the preservation

of the Tłıchǰ language, culture and traditions. The Tłıchǰ Government will consider all applications and proposals for uses on Tłıchǰ Lands, but will guide itself with the Tłıchǰ Land Use Plan.

## **GEOMET: USING EXPLORATION AND RESOURCE DATA TO INFORM MINE PLANNING AND METALLURGICAL PROCESSING**

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Many mining companies are faced with communication breakdowns between the exploration and development stages of a project. This siloing is generally unintentional, as a typical project may change ownership several times over several decades before it reaches feasibility and development. Whereas exploration projects commonly generate plenty of high-quality, quantitative data with great spatial resolution, this information is often ignored in subsequent deposit modelling and mine planning. Instead, deposit models tend to rely to a large extent on subjective, non-standardized, qualitative classification of geological materials obtained through visual logging of drill core, such as rock type, texture, mineral abundance, and alteration styles and intensities. When exploration projects advance to feasibility studies, the required quantitative data are then obtained through expensive metallurgical test work and detailed mineralogical quantification (e.g. QEMScan, qXRD). However, these detailed tests are generally only performed on a small number of large composite samples, the results of which are extrapolated throughout the deposit,

inherently underrepresenting the true spatial variability of the measured parameters.

Fortunately, the available assay data from exploration drilling can play an important role in bridging this divide at relatively low cost. Geochemical data obtained during all stages of the project provide comprehensive data coverage at much greater detail and spatial resolution. Lithochemical data analysis can be used to quantify mineralogy and geological processes, which in turn allows for the estimation of key metallurgical performance parameters that are required for accurate deposit modelling and domaining. Early-stage implementation of an adequate sampling program and full utilization of the data are essential to assess the true mineral potential of a deposit. Although a geomet assessment may or may not increase the on-paper grade and tonnage of a resource, it can dramatically reduce the uncertainty and risk involved with its development and production.

## **SALTY FLUIDS, SUBDUCTED SLABS AND NWT DIAMONDS**

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Diamonds from the Ekati and Diavik mines have provided a wealth of information on diamond forming processes beneath the Slave craton. Fluid-rich “fibrous” diamonds trap some of the fluid from which the diamond is growing and hence provide a unique means to characterize directly the fluids that percolate through the deep continental lithospheric mantle. On a world-wide basis, Ekatic and Diavik fluid-rich

diamonds trap an anomalously high proportion of fluids that are “salty” or high saline in composition, with high Na and Cl contents. The origin of these “salty” fluids has been something of a mystery. Here we show the first clear chemical evolutionary trend identifying saline fluids as parental to silicic and carbonatitic deep mantle melts, in diamonds from the Northwest Territories, Canada. Fluid-rock interaction along with in-situ melting cause compositional transitions, as the saline fluids traverse mixed peridotite-eclogite lithosphere. Moreover, the chemistry of the parental saline fluids - especially their Sr isotopic compositions - and the timing of host diamond formation suggest a subducting Mesozoic plate under western North America to be the source of the fluids. Our results imply a strong association between subduction, mantle metasomatism and fluid-rich diamond formation, emphasizing the importance of subduction-derived fluids in impacting the composition of the deep lithospheric mantle.

## **DIAVIK MINE ENVIRONMENT UPDATE**

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Since 2003 Diavik Diamond Mines Inc. has been mining diamonds from kimberlite pipes located below the waters of Lac de Gras. Monitoring and mitigating our impact on the local environment has been a core value at Diavik since our initial discovery. The mine was designed, and is operated, in a manner to reduce our overall environmental footprint and ultimately allow for a safe and efficient closure.

A core team of scientists and technicians are responsible for monitoring the air, water,

wildlife and regulatory compliance at the mine site. This presentation will focus on the work of this dedicated team.

## **ADAPTING TO CHANGE: UPDATE ON ENVIRONMENTAL ASSESSMENT POLICY AND PROCESS INITIATIVES IN THE MACKENZIE VALLEY, NORTHWEST TERRITORIES**

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The Mackenzie Valley Review Board is responsible for the Environmental Assessment process in the Mackenzie Valley, Northwest Territories, a process which is designed to prevent significant adverse environmental impacts and to ensure the views of aboriginal people and the general public are considered. With an internal goal of ongoing improvement, and the need to respond to legislative amendments (e.g., timelines), the Review Board has undertaken numerous initiatives aimed at enhancing environmental assessment in the Mackenzie Valley. We will outline the organization's general approach and priorities, and provide an overview of its current policy and process initiatives, including: guidance documents, timeline tracking, practitioner's workshops, and transboundary cooperation.

## **KENNADY NORTH PROPERTY: 2015 FIELD SEASON UPDATE**

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The Kennady North Property, wholly owned by Kennady Diamonds Inc. (KDI) is located 300 km northeast of Yellowknife adjacent to the DeBeers/Mountain Province Gahcho Kué mine site. 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, hand and RC till sampling and diamond drill programs.

In 2015, KDI completed a large diameter reverse circulation drill program to bulk sample the southern lobe of the Kelvin kimberlite. Following the RC program, diamond drilling and ground geophysical surveys continued in the Kelvin-Faraday Corridor (KFC) and at various exploration targets on the property including the MZ Dyke and Doyle Sill.

The field season started in January with the completion of the Kelvin camp and the construction of the RC drill icepad on Kelvin Lake. The pad and a seasonal spur road off the Gahcho Kue seasonal road were completed to coincide with the opening of the Tibbit-Contwoyto winter road and facilitated the mobilization of two large diameter RC rigs operated by Midnight Sun Drilling Inc. to the property.

A total of 446 tonnes of the Kelvin kimberlite were obtained via RC drilling between February 19 and April 2. The bulk sample was processed via DMS at the Saskatchewan Research Council in Saskatoon.

One diamond drill commenced drilling prior to the RC program and two other drills commenced on the heels of the RC program. A total of 31,000 meters of NQ and HQ core have been drilled during 2015 to the end of October. Drilling at Kelvin has focused on



geotechnical and related environmental baseline work as well as further delineation of the pipe-like body with the aim of generating a NI43-101 compliant resource in early 2016. Diamond drilling at the Faraday group of kimberlites delineated the Faraday 1 and Faraday 2 kimberlites. These pipe-like bodies share a similar pipe-like structure and internal geology to the Kelvin kimberlite. Aurora conducted 8848 stations of ground gravity and 521.32 line-kilometers of Ohmmapper™ capacitively coupled resistivity in the KFC, MZ dyke, and Doyle Sill during March and April. A 87 line-kilometer bubble seismic survey over the Kelvin, Faraday and MZ complexes was conducted in September.

Kennady Diamond Inc. is very encouraged by the exploration results to date and anticipates a successful and exciting 2016.

## **NWT POST DEVOLUTION – INTERGOVERNMENTAL COUNCIL AND RESOURCE REVENUE SHARING**

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As part of the Devolution Agreement, the Government of the Northwest Territories and the Aboriginal parties to the Devolution Agreement signed two other agreements:

- The NWT Intergovernmental Agreement on Lands and Resources Management
- The NWT Intergovernmental Resource Revenue Sharing Agreement

Both these agreements are ground breaking

in that they not only provide Aboriginal parties with a voice in lands and resource management, the agreements also spell out how resource revenues will be shared. This session will provide an update on the work of the Intergovernmental Council and outline the resource revenue sharing that has occurred to date.

## **GEOLOGICAL AND STRUCTURAL INTERPRETATION OF THE JAY KIMBERLITE HOST ROCKS**

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The Ekati property is located above an eastward-dipping Archean suture in the central part of the Slave Structural Province of the Canadian Shield. The bedrock geology comprises supracrustal rocks (metamorphosed greywacke-mudstone turbidites) of the Neoproterozoic post-Yellowknife Supergroup that are intruded by syn to post-tectonic plutons, made up predominantly of granite, granodiorite, and tonalite. In addition, five mafic Proterozoic dyke swarms, ranging in age from ca. 2.23 to 1.27 Ga, intrude the area. The area is intersected by several mafic dykes, belonging mainly to the Malley, MacKenzie, and Lac de Gras dyke swarms.

To date, approximately 150 kimberlites have been discovered at Ekati ranging in age from ca. 45 to 75 Ma, intruding Archean metasediments and granitoids of the Slave Craton. In addition to the 150 kimberlites on the Ekati property, more than 240 confirmed kimberlites have been discovered to date in

the region known as the Lac de Gras kimberlite field. The kimberlites represent the only evidence for Phanerozoic igneous activity within the area. Kimberlites on the Ekati property show an apparent bias in the type of host rock they intrude and are commonly associated with faults or dykes of various orientations.

The Jay kimberlite pipe is located in the southeastern quadrant of the Ekati property. It is approximately 25 km southeast of the Koala cluster (including Panda, Koala, Koala North and Beartooth kimberlite pipes), and 7 km north-northeast of the Misery Main pipe. Based on available geological data consisting of geophysical surveys, geological maps and borehole data, the Jay kimberlite pipe appears to be hosted within post- Yellowknife Supergroup granitic rocks, ranging from granite to granodiorite in composition. It is interpreted to be emplaced along a regional lithological contact between granitoid rocks and Yellowknife Supergroup metasedimentary rocks that were covered by a now eroded veneer of poorly consolidated muddy sediments. A diabase dyke trending approximately east-west occurs to the north of the Jay kimberlite pipe. Despite the available data, geological and structural

settings of the Jay host rocks were still not well understood.

This work represents the first comprehensive geological interpretation of the host rocks within the Jay pipe setting. The proposed interpretation will be based on the following:

- a detailed review, compilation, and interpretation of previously published geological work in the area;
- interpretation of high-resolution light detection and ranging (LiDAR) data;
- high-resolution orthophotos and airborne geophysical data;
- geological data from delineation and geotechnical boreholes drilled between 2005 and 2007, and the recent 2014 and 2015 drilling programs at the Jay pipe area.

An implicit modelling approach has been used to develop a three dimensional geological and structural model of the Jay pipe host rocks based on the preliminary interpretation. Ongoing studies aim to decode the geological and structural controls on the Jay kimberlite emplacement, along with its relationship with the nearby Misery kimberlite cluster.

## Abstracts - Poster Presentations

Presenting Author denoted by \*

### PRELIMINARY LITHOGEOCHEMISTRY AND GEOCHRONOLOGY OF PEGMATITES OF THE HALL PENINSULA, AND IMPLICATIONS FOR REE MINERALIZATION POTENTIAL

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A number of granitic pegmatites on the Hall Peninsula were sampled in 2014 as part of an ongoing study to determine the petrogenesis and composition of the pegmatites, and to evaluate their metallogenic potential, with a particular focus on rare metals, rare-earth elements, and/or gems. To date, whole-rock lithogeochemistry, spot mineral geochemical analysis via laser ablation multiple-collector inductively coupled-plasma mass spectrometry, and LA-ICP-MC-MS U-Pb geochronology on zircons and monazites have been completed on various subsets of the more than 70 samples collected as part of the project. This poster presents selected preliminary data available from these analyses to date.

### DEVELOPING A HYDROTHERMAL MODEL FOR POLYMETALLIC NI-CO-BI-AG- SB-AS-U VEINS AT BLANCHET ISLAND AND COPPER PASS, SOUTHERN SLAVE PROVINCE, NORTHWEST TERRITORIES

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Polymetallic veins (Ni-Co-As-Bi-Ag-Sb - U), traditionally defined as “five-metals association” veins, occur in the southern Slave Province and East Arm basin of Great Slave Lake, Northwest Territories. At Blanchet Island and Copper Pass, this style of mineralization was previously mined, and are being investigated in this study using a variety of bulk and microanalytical (geochemical and geochronological) techniques. These mines produced a minor amount of cobalt, nickel and native silver. Similar style deposits, albeit much larger, have also been mined in the Thunder Bay and Cobalt districts of Ontario and Great Bear Lake, Northwest Territories. The latter has been mined for native silver and uraninite in the past. At Blanchet Island, vein hosted-styles of cobalt-nickel mineralization occurs within carbonate sedimentary rocks of the Paleoproterozoic Great Slave Supergroup, adjacent to (and within) monzonitic sills and skarns in host carbonates. At Copper Pass, located in the southern limit of the Slave Province, mineralization occurs as massive nickeline

veins that cross-cut Archean metavolcanic rocks and pegmatite dykes. Maximum vein thickness reaches 8 cm, parallel to a local shear zone, both striking 50 degrees. Veins bifurcate locally before anastomosing back to a single vein. Localized uranium at Copper Pass is generally most concentrated where veins cut older aplite dykes, and uranium levels reach 230 ppm within the vein-aplite margins. However, when compared to Echo Bay and Eldorado mines of the Great Bear Lake district, Copper Pass contains low uranium levels. In-situ barren quartz-carbonate veins run parallel to mineralized veins demonstrating no cross-cutting relationships at outcrop scale. Nickeline mineralization also occurs as cements to breccias of altered country rock, but this is generally preserved in float only. Analysis of the host rocks, mineralized veins, and fluid inclusion analysis will be conducted through transmitted and reflected light microscopy and scanning electron microscopy to determine paragenetic history, paragenetic overprint and fluid generations. Micro-thermometry of fluid inclusions will reconstruct salinity and homogenization temperatures of source fluids. Raman spectroscopy and LA-ICP-MS will compliment micro-thermometry be used to determine fluid inclusion chemical composition and evolution of hydrothermal fluids as they relate to ore formation.

**NORTHWEST TERRITORIES  
GEOLOGICAL SURVEY  
COLLECTIONS PROGRAMS  
2015: URGENCY TO PRESERVE  
DETERIORATING RESOURCES**

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This year the Northwest Territories Geological Survey (NTGS) received new

funding to take care of many large archival collections in its care. Two initiatives were launched to preserve valuable sample collections using these new resources.

The NTGS Geological Materials Storage Warehouse and viewing facility was the flagship project of these new initiatives. This project saw the construction of a new 920 m<sup>2</sup> cold storage warehouse, along with the partial renovation of an existing building to provide a heated examination area for the collection. The warehouse is designed with five tiers of racking to store the NTGS core collection, rock samples, sample powders, thin sections, analytical rejects, and other geological materials. A narrow aisle forklift has been acquired in order to stow and retrieve pallets of materials, and deliver them to the heated viewing area. The NTGS core collection is currently housed out of doors at the Giant mine site, and is showing its wear from this less than ideal arrangement. Over one person-year has been spent getting the collection ready to move into the new warehouse this coming spring, and there is still much more to do.

NTGS also launched a core rescue program this year allowing four projects aimed at preserving core in the field. NTGS staff worked on core from Kidney Pond (Gordon Lake, Au) and Sunrise (Beaulieu River, VMS). Activities at these mineral deposits included removing core from degraded racks, cross stacking, relabeling or re-securing box labels, fire-smarting core storage areas, and related chores.

Finally, contribution agreements supported core preservation initiatives at two other sites. At the Terra past producing mine, DEMCo minerals removed over eight kilometres of core from ailing core racks, then relabeled and cross-stacked the core. At the Dharma diamondiferous kimberlite,

northwest of Great Bear Lake, Sanatana Minerals collected, relabeled and returned to Yellowknife representative samples of the pipe. The core samples from Dharma have been donated to the NTGS and entered into the core collection.

## LENA WEST CHROMITES

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Most chromites found in kimberlites are not unequivocally kimberlitic. Many can be found in other rocks. They are found widespread across Lena West and are important on the Talmora property where paleo-lateritic weathering has destroyed most silicate kimberlite indicator minerals (KIMs).

Most chromites in the area of the Dharma kimberlite have a restricted range of compositions, are not related to the kimberlite and may not be kimberlitic. Peak chromite counts lie to the southwest of Dharma and similar chromites are recognised in glacial trains to the WSW and NNW and some probably reached the Talmora property. The number of chromite grains decrease down-ice from Dharma indicating that elevated counts on the Talmora property must have a local source. Some Talmora chromites are similar to those near Dharma but others have a wider range of compositions. There are no surface exposures of non-kimberlitic chromite bearing rocks on the Talmora property. However, weathered kimberlite overlain by glacial overburden could be a source.

Cluster analysis was used to confirm statistically the difference between “possibly non-kimberlitic” Dharma area chromites and those on the Talmora property and the

similarity of Talmora and other Lena West chromites and the possibility that they may have a common source area.

The clustering method approach used was Expectation Maximization (EM) multivariate normal mixture modeling with covariances parameterized by Eigen value decomposition. The Bayesian information criteria (BIC) approximation determined the likely number of components in the data set that make up the clusters and the optimum covariance matrix model. The Mclust V5.0.2 program based on Fraley and Raftery (2002) was used to process TiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Cr<sub>2</sub>O<sub>3</sub>, FeO, MnO and MgO oxide assays.

Cluster analysis of the combined Sanatana and Talmora database shows that the Lena West chromites can be divided into two overlapping clusters, one dominating the Dharma area with a restricted range of compositions and is probably non-kimberlitic and one that has a wider range of compositions, is probably kimberlitic and is found elsewhere across Lena West. Although many chromites in the Talmora area have compositions similar to non-kimberlitic chromites in the Dharma area many are significantly different and have a different source. Division of only the Talmora chromites into two clusters shows that even chromites similar to those that are probably non-kimberlitic at Dharma could also be just part of clusters that have a source in the Talmora area and are rare in the Dharma area.

The long train of chromites decreasing numerically and systematically down-ice of Talmora is strong evidence that the Talmora area is the source of these chromites. The source of the Simpson and Ramparts KIM anomalies has not been found. The similarity of the chromites in the train down-ice of Talmora to those of the Simpson and



Ramparts areas suggests that they may have a common source. The Simpson and Ramparts chromites could be related to those on the Talmora property through dispersion in a pre-Cretaceous basin.

## **GEOPHYSICAL EVIDENCE FOR GREAT BEAR FAULT ZONE**

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The Slave “Diamond Corridor” is a north northwest trend that appears to have controlled the emplacement of the most significantly diamondiferous kimberlites of the Slave craton of northern Canada and any extension of the corridor is prime diamond exploration country. A northern extension of the corridor into the Lena West diamond area of the Northwest Territories that includes the diamondiferous Darnley Bay and Dharma kimberlites requires major left-lateral displacements (~350km) that are not generally recognized and are not identified in the surface geology.

Major continental scale wrench faults were recognized by Zolnai (1991) including the Great Bear Fault Zone. Analysis of the available geomorphological and geophysical (magnetic, seismic and gravity) information supports his ideas. Euler deconvolution analysis of regional airborne magnetic surveys covering Lena West shows little response in the near surface platform rocks but outline strong linear breaks coinciding with other evidence of faulting in the deeper basement rocks.

A seismic velocity model of North America data SL2013NA computed by Scheffer et al (2014) on a ~280km triangular grid shows large scale regional structures and confirms the existence of a cratonic basement

(Mackenzie Craton) under the Lena West Paleozoic sedimentary rocks. The final model was made public at 3D grid spacing of 0.25 degrees longitude and latitude covering North America from 25km to 575km depth at 25km intervals. Extractions from this grid were made to produce east-west cross-sections.

The character of the seismic velocity response shows little change from the south end of the Slave craton to the north end of the Mackenzie craton. However, a major left lateral displacement (~250km) of deep structures within the mantle (~200km to below 575km depth) is recognized in the region of the Great Bear Fault Zone suggesting that the Mackenzie Craton is simply the faulted northern extension of the Slave Craton. There are marked changes to the character of the seismic velocity model across the recognized faults to the south (Great Slave Shear Zone) and to the north (Tuk Fault).

Regional sampling programs across Lena West have recovered widespread kimberlite indicator minerals with good diamond association chemistry, including 18 diamonds in field samples. However, the source of these indicator minerals has not been found. Extension of the Slave “diamond corridor” through Lena West is incentive for further exploration of the region, focused on a north northwest striking zone that includes Darnley Bay and extends south to Great Bear Lake.

## SLAVE PROVINCE SURFICIAL MATERIALS AND PERMAFROST STUDY SUMMARY POSTER

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In 2014 the Northwest Territories Geological Survey (NTGS) initiated the Slave Province Surficial Geology and Permafrost Study (SPSMPS) in NTS sheets 76C and 76D. The SPSMPS is a two year collaborative government –industry – academic research project funded through the Strategic Investments in Northern Economic Development program of the Canadian Northern Economic Development Agency.

The main objectives of the SPSMPS are to:

- Produce a 3D database of indicator minerals to identify areas of high mineral potential;
- Advance our understanding of glacial history to aid in mineral exploration;
- Update surficial maps in targeted areas;
- Study the impact of climate change on permafrost and terrain sensitivity to inform potential infrastructure development.

In order to accomplish these objectives, 235 boreholes were drilled to sample a wide variety of glacial sediment, over 1250 samples were collected, and approximately 240 thermistors were installed at 41 LIDAR surveyed sites. In addition, over 1500 km<sup>2</sup> of field mapping and approximately 150 line km of ground geophysics were carried out. Large proprietary indicator mineral and remote sensing datasets along with logistical support were generously provided by our industry partners.

Our industry partners include the Canadian Mining Institute Research Organization (CAMIRO), Dominion Diamond Ekati Corp, Diavik Diamonds Mines Inc., North Arrow Minerals Inc., Peregrine Exploration Ltd., Artic Star Exploration Corp., New Nadina Explorations Limited, and TNT Mineral Science. Academic Partners include Dr. Martin Ross (University of Waterloo), Dr. Brent Ward (Simon Fraser University), Dr. Stephan Gruber (Carleton University) Dr. Don Cummings (Carleton University) and the Dr. Peter Winterburn (University of British Columbia). This work was carried out by or with support from Aurora Geosciences Ltd.

The SPSMPS also included numerous targeted studies such as:

- A 3D indicator mineral entrainment study to show how indicators get from source to surface;
- A 3D GPR survey of the Exeter Lake Esker to better understand esker formation, material transport distances and ideal sampling mediums for indicator minerals;
- LIDAR and drill assisted surficial mapping of enigmatic landforms associated with glacial outwash corridors in the region;
- Drill assisted surficial mapping to determine detailed local ice flow direction and glacial history associated with sourced and un-sourced indicator mineral trains in areas with complex and poorly understood surficial geology;
- A network of thermistors was established to determine variability in ground temperatures and monitor the impact of climate change on permafrost in a wide variety of terrain types;
- A comparative surficial geochemistry and soil gas study over a buried kimberlite;

- Developing and refining a reliable methodology for rapidly identifying indicator minerals below 500 µm in size using hyperspectral imaging;
- Developing a snowmobile towed ground geophysical method for rapidly determining overburden depth to bedrock.

**CRYPTIC STRUCTURAL  
CONTROLS ON  
METALLOGENY PATTERNS AS  
REVEALED BY THE  
DISTRIBUTION OF HEAVY  
MINERALS IN STREAM  
SEDIMENTS FROM THE FLAT  
RIVER AREA, MACKENZIE  
MOUNTAINS, NWT.**

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In 2014, a silt, water, and bulk stream sediment survey was conducted along the western Mackenzie Mountains by the Northwest Territories Geological Survey and the Geological Survey of Canada, collecting material and observations from 190 sites. Regional stream sediment surveys have been carried out over much of the Canadian Cordillera using the National Geochemical Reconnaissance (NGR) methodology including a grab sample of silt-sized stream sediment, and a corresponding water sample, at a target sample density of one sample per 13 km<sup>2</sup>. The methodology also includes the collection of a coarser-grained and volumetrically-larger samples at one sample per 26 km<sup>2</sup> for heavy indicator minerals, which are picked for kimberlite indicator mineral grains, magmatic massive sulphide indicator minerals, and gold grains.

The results for the most recent survey demonstrate the Flat River region's anomalously high metal potential. For some commodities, such as tungsten and lead-zinc, this elevated endowment is well known and represented by two world-class deposits, Cantung and Howards Pass, respectively. However for other elements, intriguingly anomalous samples contain suites of minerals including gold, cassiterite and sapphire grains that are inconsistent with the known showing types, suggesting that further exploration for different mineralization styles is required in this area.

Even for the known mineralization, the geology of this region remains poorly understood. Structural controls, such as faults, have been suggested (Goodfellow + Jonasson, 1987; Hart + Lewis, 2006) as a mechanism for focusing economic mineralization but rarely have the faults been identified, nor has the history of those faults been defined to substantiate the hypothesis. Reconnaissance mapping and geophysical surveys along the March Fault have supported the interpretation of the fault as a long-lived crustal-scale structure, which played an important role in controlling the mineralization in the region.

**UPDATED BEDROCK  
GEOLOGY OF PART OF THE  
MISTY CREEK PALEO-  
EMBAYMENT, MACKENZIE  
MOUNTAINS (NTS 106B)**

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An updated bedrock map that covers most of the Misty Creek paleo-embayment in the northern Mackenzie Mountains will soon be available. The embayment began to develop

in the western Laurentian margin during the Cambrian period and persisted, episodically subsiding, until the late Middle Devonian. It is defined geologically by belts of platform-to-margin transition facies that trace the embayment margins, and a NW-trending belt of basinal facies that follows the basin axis.

Previously published maps are preliminary 1:250,000 scale. The Selma project undertook to provide more-detailed geological knowledge of the basinal facies. Data were compiled from recent field work, previously published bedrock and stratigraphic studies by government and academia, and maps, stratigraphic sections and structural data provided by exploration companies. Interpretations were refined using radiometric data from a 2011 NTGS airborne survey. A B.Sc. thesis on the volcanic rocks of the Porter Puddle complex was completed in 2013 by B. Williams. Lithochemical results and a preliminary map were published in 2014. The stratigraphy and metallogenic potential of the region was described in Forum presentations in 2011-2013.

The map shows Neoproterozoic and Cambrian units trending NW-SE on either side of a central belt of Lower Paleozoic basinal sedimentary and volcanic rocks. A NE-trending structural break separates the southeastern domain, in which a NW-plunging anticline-syncline pair adjacent to a NW-trending fault exposes both the oldest and youngest basinal strata, from the northwestern part of the embayment, where major folds plunge SE. Platformal strata are present in the southeastern domain and east-central area, including a narrow belt folded around a core of basinal strata in the central area.

Refined interpretations of some of the

stratigraphic units include the Middle Cambrian Hess River Fm. being deposited on a deep slope or basin floor by low-density turbidity currents and including both waning-flow and hemipelagic muds, and Cambro-Ordovician Rabbitkettle Fm. being deposited above but near storm wave base on a slope prone to collapse and allodapic shedding. The Ordovician-Silurian interval includes Duo Lake Fm., Cloudy Fm., and an unnamed skeletal carbonate unit. Cloudy Fm. includes two large olistostromes, one previously unrecognized. The volcanic Marmot Fm. erupted from two magmatic centers, the Dudley Lake and Porter Puddle complexes, both of which contain extensive breccia/fragmental facies. An unusual Middle Devonian mixed volcanogenic and skeletal-limestone unit underlying Tsetso and Comesall fms is tentatively identified as a variant of lower Tsetso Fm. It indicates the proximity of Middle Devonian volcanism. Black shaley lime mudstone of Early-Middle Devonian Hailstone Fm. overlies Duo Lake and Cloudy fms., and passes upward into black siliciclastic shale of the Middle-Late Devonian Horn River Fm., often with a thin intervening succession that probably correlates with lowermost Hare Indian Fm. Hailstone Fm. in the southeastern domain exhibits a lateral transition to forereef-talus deposits of Grizzly Bear Fm. Porous transitional Hailstone Fm. in the cores of tight anticlines in this area is identified as a target for Carlin-type gold. Siltstone, sandstone, and shale of the Imperial and Hawthorne Creek fms. are the youngest strata in the map area.

## **GEOSCIENCE TOOLS FOR SUPPORTING ENVIRONMENTAL RISK ASSESSMENT OF METAL MINING**

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We present new research plans to apply an innovative, multidisciplinary research methodology to reconstruct variations in climate, geochemistry, permafrost, and ecology over the past ~1000 years along a north-south transect from Yellowknife, NWT, to Hope Bay, NU, in the Slave Geological Province. The project mandate is to assess the cumulative effects of natural and human-driven changes, particularly climate change, on the transport and fate of metals and health of regional ecosystems in areas of high resource potential in the Canadian North. Using an integrated paleoecological-geochemical modeling and traditional knowledge approach, this study will be focused on three areas; Yellowknife, Courageous Lake, and Hope Bay. Sediment cores will be collected from lakes and permafrost peatlands and analyzed using a variety of proxies. Using our results in conjunction with existing regional data we will establish geochemical baselines in sediments and soils, as well as assess and predict the potential impact of climate change and land disturbance on environmental metal fluxes. This research will support and improve decision making, environmental stewardship, and Canada's regulatory processes to ensure sustainable development of Canada's North.

## **INTEGRATED FREEZE CORE - ITRAX MICRO-XRF SCANNING AS A NON-DESTRUCTIVE METHOD TO DETERMINE BASELINE GEOCHEMICAL CONCENTRATIONS: PRELIMINARY RESULTS FROM MILNER AND DAIGLE LAKE, YELLOWKNIFE, NORTHWEST TERRITORIES**

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The Northwest Territories "Mine Site Reclamation Policy" stipulates that companies must return environmental systems impacted by mining operations to pre-disturbance conditions. As part of this policy, "Mine Closure and Reclamation Plans" are required before the initiation of mining operations. Understanding the baseline concentrations of contaminants from natural and anthropogenic sources is paramount to the development of a remediation plan. The sedimentary record of local lacustrine basins is one setting where the dynamics of prior-contamination vs. natural elemental concentrations can be examined. Given the low-sedimentation rate lakes common in the subarctic, the high-resolution analysis required to decouple anthropogenic and natural variations in metals of interest (e.g. As) can be technically difficult. Developing analytical



protocols that can be used to rapidly and cost-effectively determine environmental baseline conditions will greatly aid mine developers and policy makers when establishing both discharge concentrations and “Mine Closure and Reclamation Plans”.

Many of the conventional coring methodologies used in lake studies tend to homogenize the upper sedimentary record and in low sedimentation rate environments this will obscure any anthropogenically produced contaminant signals. Freeze coring solves this issue by freezing sediment in situ to preserve the soupy sediment-water interface, as well as the sediment stratigraphy. Unfortunately, freeze cores, typically do not provide enough sedimentary material to obtain traditional geochemical analysis (ICP-MS) results at a resolution adequate to identify possible anthropogenic influences. Analyzing sediment cores using ICP-MS at high resolution (mm-scale) can also be prohibitively expensive. The ITRAX high-resolution x-ray-fluorescence core scanner (micro-XRF) can be used to rapidly analyze sediment cores at sub-mm resolution for a fraction of the cost of ICP-MS. Although the results of micro-XRF are only semi-quantitative due to issues with sediment heterogeneity, moisture content and topography-induced artefacts, recent studies have been able to generate quantitative elemental concentrations by calibrating micro-XRF data to quantitative geochemical results obtained from selected core intervals.

Prior to this research, freeze cores have not been analyzed using a micro-XRF due to the long scan times required. ITRAX micro-XRF analysis is conducted at room temperature, and freeze cores rapidly lose their integrity once they begin to melt. To develop a procedure for analysing freeze cores with a micro-XRF scanner, freeze

cores were collected in June 2015 from Milner and Daigle lakes, fifteen kilometres north of Yellowknife, with the assistance of TerraX Minerals Inc. We designed custom-built refrigerated containment vessels suitable for keeping sediment cores frozen during ITRAX scanning. These containment vessels kept 10 cm long freeze core segments frozen for > 1 hour, sufficient time to scan freeze cores at 0.5 mm resolution. As ITRAX micro-XRF scanning is non-destructive, the scanned material from freeze cores can be used for other purposes. The scanned sediment from Daigle and Milner lakes was sent to ACME labs for ICP-MS analysis, and the results used for comparative and calibration purposes. The results of this research indicated that ITRAX micro-XRF core scanning of freeze cores is a viable and inexpensive alternative to ICP-MS analysis.

## **SURFICIAL GEOLOGY MAPPING FROM HIGH- RESOLUTION LIDAR AND ORTHOPHOTOS IN THE LAC DE GRAS AREA - PRELIMINARY RESULTS**

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The Geological Survey of Canada, as a part of the Slave Province National Mapping programme, produced the only published surficial geology maps of the Lac de Gras area, Northwest Territories in the mid-1990s. The Laurentide ice sheet glaciated the area, and these glacial deposits can mask kimberlite pipes. Thus, locating kimberlite deposits by drift prospecting requires detailed knowledge of the surficial geology

and glacial history. We mapped the surficial geology of the Ursula Lake area, on the north side of Lac de Gras, at a scale of 1:20 000 using high-resolution orthophotos and a one metre LiDAR digital elevation model obtained by Dominion Diamond Ekati Corporation. Fifteen days of field mapping was also carried out in the area.

LiDAR and orthophoto data can be combined to create three-dimensional computer images. This allows us to examine the systematic spatial relationships between different surficial materials and landform types in more detail than has previously been possible. In the Ursula Lake area many meltwater corridors can be identified in the high-resolution imagery. These corridors are typically 300-1500 m wide, forming a dendritic network. Between the corridors, sandy till of varying thickness overlies bedrock. Within corridors, glaciofluvial landforms and scoured bedrock are common. Eskers are only present within corridors in the map area. Also associated with corridors are common enigmatic mounds. These mounds are commonly found in groups and are typically 20-100 m wide and rise 5-15 m above the surrounding area. Some are elongated in the direction of ice flow while others are symmetrical or elongated at an angle to ice flow direction. The mounds are typically composed of an unstratified to weakly-stratified sandy diamicton containing no clay and minor silt. However, patches of well-stratified sediments do exist on parts of some mounds. Variation in the sedimentology of the mounds does not appear to be related to variations in mound morphology.

It is likely that the majority of the glaciofluvial sediments in the Ursula Lake area were deposited during the final stages of ice retreat across the area when meltwater volumes were high. We suggest that the

corridors were formed by subglacial meltwater flow. This is because glaciofluvial deposition almost exclusively occurs within corridors, very little till is found within corridors and the corridors have an undulating elevation profile in the direction of ice flow. Eskers also have an undulating elevation profile in the down-flow direction and thus must have at least in part formed in subglacial channels. Water must have played a role in the deposition of the well-stratified patches of sediment found on some mounds, however, the mounds may not be solely the product of subglacial meltwater flow. Ice flow mapping confirms the previous glacial history. Surficial mapping and a thorough understanding of sediment transport and depositional processes is critical if kimberlite indicator mineral data is to be accurately interpreted.

## **MYCORRHIZAL DENSITY AND INOCULATION POTENTIAL OF SOILS OBTAINED FROM THE TRUCK LAKE CHANNEL: A SITE AT THE REMEDIATED COLOMAC MINE**

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The Colomac gold mine, located 220 km north of Yellowknife, was operational from 1994 to 1999. During construction of the infrastructure for the Colomac mine, the broad wetland between Truck Lake and Steeves Lake was infilled to permit construction of roads and storage laydown areas. Following mine closure, connectivity

of the two lakes was restored through the construction of a new channel that was revegetated with local transplants and a native seed mix. In 2014 vegetation monitoring was augmented with assessments of beneficial soil fungi. Arbuscular mycorrhizal fungi (AMF) are soil dwelling fungi that form symbiotic associations with most vascular plants. These associations have been shown to affect seedling establishment and community composition, and therefore, may play a role in plant community establishment on disturbed sites. As an initial step towards understanding the role of mycorrhizal fungi in plant community structure at the Colomac Mine, we quantified mycorrhizal inoculum potential and spore density in soils obtained from contrasting locations in the Truck Lake Channel including the channel proper, vegetated islands within the channel and upland terrace area draining into the channel. Mycorrhizal spores were extracted from soils using the sucrose-gradient method. Spores were classified according to external morphology and density quantified. To assess soil colonization potential *Epilobium angustifolium* and *Phalaris arundinacea* seedlings were transplanted to soils obtained from the site and grown under controlled conditions. Harvested roots were fixed, stained and examined for fungal colonization using light microscopy and quantified using established protocols. Fungal spores were present in all soil samples. Three morphotypes were identified. Spore density ranged from 2-136 spores/g of soil. Fungal colonization was observed in plants grown in all soil samples, ranging from 22%-90% for *E. angustifolium* and 6%-55% for *P. arundinacea*. Soils collected from the channel were analyzed by ICP-OES for concentrations soil nutrients. Among the sample sites, phosphorous and potassium ranged from 0-0.00126 g/g of soil and 0.00054-0.001646 g/g of soil,

respectively. Relationships between fungal colonization, soil characteristics, spore density and sample site will be discussed.

## MANTLE COMPOSITION BENEATH THE DARBY KIMBERLITE FIELD, WEST CENTRAL RAE CRATON

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In Canada's North research on cratonic mantle composition has primarily focused on the Slave craton. The Darby Kimberlite field, located ~120 kilometers southwest of the community of Kugaaruk, Nunavut provides an opportunity to study the mantle beneath the Rae craton. The kimberlites erupt through lithosphere belonging to the western margin of the Committee Block that comprises much of the central Rae craton. The field contains 8 kimberlite bodies. Five of the kimberlites have proven to be diamond bearing including the 12 hectare 'Iceberg' kimberlite (Indicator Minerals-press release).

Mantle xenoliths were collected from kimberlite float above proven kimberlite targets, across the property. Most of the surface kimberlite is highly altered and hence the peridotite xenoliths they contain are generally serpentized/deeply weathered. Eclogite/pyroxenite was found at each locality visited. A total of 31 mantle xenoliths that exceeded 1 cm in maximum dimension (15 peridotites & 16 "eclogites") were selected for mineral chemistry and bulk analysis. Four peridotite xenoliths contained fresh garnet. Of these, garnet in one sample classified as harzburgitic (G10), giving a minimum pressure (geotherm 35-40mW/m<sup>2</sup>; Liu et al. Precambrian Research, in press) of 4.7 GPa, while garnets from two

peridotites plot in the lherzolitic (G9) field. Garnets from a metasomatised dunite (olivine Mg# 90.7) fell within the (G5) field. Six of the peridotites contain fresh olivine whose Mg# ranged from 89.1 to 94.3, within the mean value of 92.6, typical of cratonic peridotites. Among the samples identified as eclogite in the field, clinopyroxene compositions have low jadeite contents and hence they are strictly pyroxenites. The garnet compositions of these samples fall in the pyroxenitic (G4) and eclogitic (G3) fields (Grutter, 2004).

None of the clinopyroxenes from the peridotites or macrocrysts passed the compositional filters of Nimis and Grutter (2010) and hence no single pyroxene thermobarometry has yet been possible. LA-ICPMS analyses allowed Ni-in-garnet thermometry to be used on 13 peridotitic garnets from 3 samples. Garnet  $T_{Ni}$  temperatures (after Canil; 1999), yield temperatures between 1300-1400°C with the lowest at 1000°C. Using a preliminary geotherm calculated for the Rae craton by Liu et al. (in press) to convert  $T_{Ni}$  to depth reveals that the depths of these peridotitic garnets were sampled from 180-200km, with shallowest garnet from 145km, suggesting these peridotites were sampled from the base of the lithosphere, within the diamond stability field.

The anomalously high abundance of eclogite/pyroxenite xenoliths found in the Darby field (52% of the total number of xenoliths observed) is at odds with the abundance of eclogite thought to be present in cratonic lithospheric mantle from xenocryst studies (~1%; Schulze, 1989). The high abundance may be related to the proximity of the field to the proposed suture between the Committee Block and the Queen Maud Block to the far West of the Rae craton. Further work on these samples

includes EPMA/LA-ICP-MS work on kimberlite concentrate, whole rock geochemistry on the xenoliths, and Re-Os ages on the peridotites and eclogites/eclogites.

## POTENTIAL TIDAL INFLUENCE ON SEDIMENTATION IN THE MOUNT CLARK FORMATION, MACKENZIE MOUNTAINS, NT

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

Although the sedimentary environments have been interpreted as fluvial to shoreface, no evidence of tidally influenced sedimentation has been reported. However, recent field efforts indicate at least one locale where tides constituted a depositional agent.

During the 2015 August field season a previously undescribed outcrop was studied 2.3 km directly SW of the Unnamed Canyon locality. The outcrop locality is herein referred to informally as Waterfall Ridge. Waterfall Ridge differs from previously documented siliciclastic shorelines at Carcajou Canyon, Dodo Canyon, Two Lakes, and Mirror Lake in that sedimentary evidence of tides has been observed. These tidal indicators include; 1) bi-directionality



cross-bedding (herringbone), 2) combined-flow structures, and 3) re-activation surfaces. These units are sharp-based and are intercalated with heavily bioturbated sandstone. Laminated beds decrease in thickness and occurrence upwards, with bioturbated beds increasing in thickness and abundance. This is taken to indicate an upwards deepening. The heavily bioturbated beds are interpreted to have been deposited between actively migrating dunes, which sharply truncate the inter-dune bioturbated lithologies.

## **MULTI-SPECIES MONITORING USING WINTER WILDLIFE TRACK SURVEYS IN THE SAHTÚ SETTLEMENT REGION**

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Recent exploration activity in the Sahtú Settlement Area for shale oil has highlighted the need to establish collaborative monitoring programs to assess cumulative impacts on wildlife. Long-term information about the distribution and population trends of wildlife within and outside areas of current shale oil exploration in the Sahtú is generally lacking for many species. Development of standardized monitoring programs that can involve community members and be applied at a regional scale by communities, industry and government will help to address this gap. A pilot study was undertaken in the community of Tulita in winter 2014 to initiate the development of a long-term winter wildlife track survey program to assess the link between

abundance and occupancy of different furbearers, ungulates and predators and changes in landscape structure and composition over space and time. Track surveys were conducted on 5 routes around the community of Tulita by snowmobile. Tracks and other wildlife sign were recorded by taking geo-referenced photos using three different devices, including a rugged hand-held computer equipped with the Trailmark™ mobile data collection application. Location accuracy was similar between the hand-held computers and GPS units with integrated digital camera, but cameras with built-in GPS provided much less reliable location data. The advantage to using hand-held computers with a customized data collection application is that all relevant information can be entered directly in the field and uploaded to a remote server at the end of each day. Experience from the first winter of data collection suggests that this technology could provide an efficient and standardized means of data collection that can be easily adopted by a variety of users. Having youth and harvesters work together to collect the data provides an excellent opportunity for knowledge exchange. Data collected from this pilot project and a previous track survey program conducted by Explor is currently being used to determine appropriate landscape cell sizes and survey segment lengths for different species for use in occupancy analysis. This approach should allow us to assess and generate predictions about spatial and temporal relationships between species distribution, population trend and landscape disturbance at a regional scale.



## DEFORMATION HISTORY OF THE BLACK BAY FAULT AND IMPLICATION FOR FAULT- CONTROLLED U AND REE MINERALIZATION

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The Black Bay Fault (BBF) is a major northeast-southwest trending crustal feature in the South Rae province of the Canadian Shield, extending from northern Saskatchewan (SK) into the Northwest Territories (NWT). Few studies have been completed on the BBF in SK, and have been focused around Uranium City, or around the Hoidas REE deposit which is associated with splays of the BBF. The extension of the BBF in the NWT is primarily based on aeromagnetic surveys.

As a part of the GEM2 South Rae joint project with the GSC and the NWT Geological Survey, the continuation of the BBF into the NWT was examined in order to better understand its deformation history and potential implication for U and REE mineralization. During the 2015 field season, large scale 1:250 000 regional mapping occurred throughout the Abitau Map sheet (NTS 75B) and more detailed mapping was focused around Insula Lake and Tazin River, NWT.

Preliminary findings support the continuation of the BBF through the NWT along the lineament defined by aeromagnetic and topographic surveys. Domains bounded by the BBF are strongly metamorphosed and often contain a

prominent east-west foliation. Proximal to the BBF, a persistent overprinting foliation striking NNE is observed along with NNE dextral shear bands transposing the regional east-west gneissic foliation. Shear sense of the fault has been observed as predominately dextral, with Z-folded syn-tectonic pegmatites and right step-up deformed feldspar porphyroclasts present throughout the zone of ductile overprinting. However, S-folded gneissic layering was present in some locales, and sigma and delta clasts indicating a sinistral shear sense were observed. These sinistral indicators were commonly found in regions with a large degree of strain heterogeneity, likely indicating sinistral motion occurred initially along the BBF and was subsequently overprinted by later dextral reactivation of the fault.

Some boudinaged Z-folded pegmatites were observed, potentially indicating either late sinistral motion occurred along the BBF, or may be evidence of transpression. Quartz-filled tension gashes oriented sub-perpendicular to perpendicular to the trace of the fault offer additional evidence of transpression.

Unlike what has been observed around Uranium City, minimal brittle deformation was observed in the NWT to date, and only a few areas with strong strain heterogeneity showed late brittle-ductile deformation. Compared to what has been reported in Saskatchewan, augen to straight gneisses are more common than mylonites near the fault, possibly indicating differential uplift has occurred along the structure. The region around the Insula Lake contained higher metamorphic grade rocks compared to those around the Tazin River in the south, further supporting a differential uplift hypothesis.

Multiple radiometric anomalies were

identified adjacent to the BBF with mineralization zones running parallel to the fault, likely along splays similar to what is observed in SK. Near to the SK border, the anomalies are hosted by late felsic alkali intrusions while 100 kms further north, the anomalies contain mineralization features similar to Hoidas, clinopyroxene-feldspar-allanite-magnetite veins hosted in a syenite. Further research will focus on constraining the timing of deformation, and examine the northern continuation of the BBF.

### **GLACIAL DYNAMICS, SEDIMENT DISPERSION, AND PRELIMINARY 3D FRAMEWORK NEAR LAC DE GRAS, NWT: YEAR 1 RESULTS**

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The discovery rate of near-surface economic kimberlites is declining and exploration has shifted to more complex settings and targets masked by thick glacial sediment cover. In addition, a number of known dispersal trains still have no source identified. New innovative techniques and new knowledge about the glacial geology are needed. The purpose of this study is to further investigate the surficial geology and dispersal patterns in the vicinity of Lac de Gras, NT (NTS map sheets 76D 6 & 11) and integrate the third dimension by adding subsurface (3D) stratigraphy, depth-to-bedrock, and KIM data. A research study involving 3D modelling is being undertaken to create a local reconstruction of glacial ice movement and sediment deposition. One key objective is to compare the Monument indicator

mineral train that has a known source, with the Coppermine indicator mineral train that has an unknown source. The study will take into account the different ice flow phases that are recognized in the area in order to decipher their net effect on dispersal patterns. By analyzing the problem in 3D, we hope to better understand the possible effect of older ice flow phases and sediment re-entrainment processes on the formation of dispersal trains that appear to be detached from their source. Subsurface samples from reverse circulation (RC) drilling, surficial till samples, as well as groove and striation measurements, and mapping of landforms provide the necessary information to address these questions.

Preliminary results are focused on the ice flow history of the study area. Striation and groove measurements record three main regional ice flow directions. The earliest ice flow observed is to the southwest at 244°. The second recognized ice flow is to the west at 269°. The third, and most recent ice flow was measured at 305° toward the northwest. The third flow is prevalent accounting for 77% of all observations and is the dominant direction of the main KIM dispersal trains in the area. There was also an indistinct fourth flow observed at 6° north. This has been interpreted as either 1) late stage ice flow during deglaciation, 2) early ice flow, or 3) relicts from a previous glacial event. The SW flow was a strong ice flow phase; yet its net effect on surficial dispersal trains in the area are not clear. The subsurface RC data will, hopefully, bring new insights into this problem.

## ECOLOGICAL RESPONSES TO LEGACY CONTAMINANTS FROM HISTORIC GOLD MINING OPERATIONS IN YELLOWKNIFE LAKES

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The scale of arsenic contamination in Yellowknife lakes located near Giant Mine and Con Mine is known to be extensive, yet the ecological impacts of long-term exposure to arsenic contamination are poorly characterized at present. A lack of baseline data prior to the development of Giant Mine severely hinders our ability to assess the ecological response of lakes impacted by legacy mining activities. Several groups of biological organisms that are key ecological indicators leave identifiable remains preserved in lake sediments. Consequently, lake sediment cores can be used to reconstruct these missing data (the field of paleolimnology) to provide a long-term assessment of ecosystem changes in lakes impacted by gold mining. In particular, the analysis of subfossil Cladocera (microcrustaceans) can provide critical insights into the long-term ecological effects of arsenic exposure in Yellowknife lakes. Cladocera are an important trophic link in aquatic food webs as primary consumers on algae and detritus, and as a food source for planktivorous fish and invertebrate predators. Several taxa are used as model organisms in classical toxicology studies, including toxicity tests for arsenic, allowing us to directly apply knowledge obtained from laboratory studies to the interpretation of changes in subfossil Cladocera from arsenic-contaminated lakes.

An investigation into subfossil Cladocera assemblage changes in Pocket Lake revealed that arsenic contamination from Giant Mine had dramatic ecological consequences, and that Cladocera were especially vulnerable. Cladocera were functionally extirpated from Pocket Lake at the height of arsenic contamination, and have not recovered despite decades of emission abatement measures. We recognize that Pocket Lake is among the most highly impacted lakes in the Yellowknife region, and may represent an isolated case. Our objective is to determine if Pocket Lake is in fact an extreme example of catastrophic ecological impacts from Giant Mine, or representative of a wider trend in mining-impacted lakes using a “top-bottom” paleolimnological approach. We analyzed subfossil Cladocera in a “top” sediment interval representing modern day conditions, and a “bottom” sediment interval deposited prior to the onset of gold mining operations in a set of 25 Yellowknife lakes, to provide a snapshot of regional changes in Cladocera since pre-industrial times. The use of a “top-bottom” approach allows for the analysis of a larger number of lakes, encompassing greater variability in lake physical and chemical properties, in order to capture the nuances in arsenic toxicity to Cladocera. This will be supplemented by analyses of detailed sediment cores at high temporal resolution in 5-7 strategically selected lakes, to directly link the timing of changes in subfossil Cladocera to increases in sedimentary arsenic, and to identify any additional assemblage shifts not evident in the “top-bottom” analysis. Using this approach, we can assess the potential resilience of freshwater ecosystems to contaminant inputs from mining activities, filling an important knowledge gap as we move forward in understanding the long-term fate of lakes impacted by legacy contamination in the Yellowknife area.

## **APPLICATION OF FE-TI OXIDE DISSOLUTION EXPERIMENTS TO THE PETROGENESIS OF THE EKATI DIAMOND MINE KIMBERLITES, NORTHWEST TERRITORIES, CANADA**

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Composition of kimberlites is ambiguous due to assimilation and fractional crystallization. We propose that the evolution history of minerals can be used to decipher the magmatic history of kimberlites. We use Fe-Ti oxides (chromite and ilmenite) from six kimberlites from the Ekati Diamond Mine and dissolution experiments to elucidate the petrogenesis of kimberlites. Experiments at 0.1 MPa and variable  $fO_2$ s in a diopside-anorthite melt show that the dissolution rate of ilmenite is highly sensitive to  $fO_2$ . No significant difference was observed in chromite. Zoning in chromite is related to the Fe-content and oxidation state of the melt. Experiments at 1 GPa explore the development of chromite surface resorption features in the system Ca-Mg-Si-H-C-O. Five kimberlites contain a low abundance of ilmenite, owing to a relatively high  $fO_2$ , though ilmenite constituted 65% of oxide macrocrysts in one kimberlite. Chromite compositions evolve from Mg-chromite to magnesio-ulvöspinel-magnetite (MUM) in all but one kimberlite where chromite evolves to a pleonaste composition perhaps as a result of rapid emplacement. The high abundance of MUM spinel and low abundance of ilmenite in the matrix could be related to the change in the stable Ti-phase with increasing  $fO_2$ . Core

compositions of macrocrysts vary for different mantle sources but rims converge to a composition slightly more oxidized and Mg-rich than chromite from depleted peridotite. Ilmenite commonly has rims composed of perovskite, titanite and MUM. We suggest a model where the kimberlite melt composition is controlled by the co-dissolution and co-precipitation of silicates (predominantly orthopyroxene and olivine) to explain chromite evolution in kimberlites. Resorption-related surface features on chromite macrocrysts show trigon protrusions-depressions on {111} faces and step-like features along the crystal edges resembling products of experiments in H<sub>2</sub>O fluid. We propose predominantly H<sub>2</sub>O magmatic fluid in Ekati kimberlites.

## **SEDIMENTOLOGY AND ICHNOLOGY OF THE MIXED CARBONATE AND SILICICLASTIC BEDS OF THE MOUNT CLARK FORMATION AT DODO CANYON, MACKENZIE MOUNTAINS, NT.**

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The Cambrian Mount Clark and Mount Cap formations are present in the Mackenzie Mountains of the Northwest Territories. The Mount Clark Formation is composed primarily of sandstone, whereas the overlying Mount Cap Formation comprises shale, dolostone, and limestone. These formations outcrop at Dodo Canyon, in the northeastern Mackenzie Mountains of the Northwest Territories. Previous work has focused on the Dodo Canyon section within a larger regional mapping program starting with the Geological Society of Canada's Project Norman in the late 1960s and early 1970s.



At this locale, the basal 20m of the Mount Clark Formation consist of mixed carbonate and siliciclastic beds. For this follow-up study, the Dodo Canyon outcrop was logged with observations focusing on bed lithologies, contacts, bioturbation intensity, and trace fossils. Representative samples of each lithofacies were collected. Hand sample descriptions were complemented by petrographic analysis to characterize the grain size, sorting, mineralogy, trace fossils and rock type of each sample. Future work will involve assessing the environments of deposition for the lowermost 20m of the Mount Clark succession at Dodo Canyon and integrating this information into a depositional framework for the Mount Clark Formation across the basin. An enhanced understanding of these lithofacies and their depositional setting will contribute to a better understanding of carbonate deposition and distribution within the Mackenzie Depocenter.

## **TECTONIC EVOLUTION OF THE TALSTON MAGMATIC ZONE: A RECONNAISSANCE STUDY**

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A 1:250:000 scale synthesis of the Northern Taltson Magmatic Zone has been released posthumously on behalf of Dr. H.H. Bostock as GSC Open File 7683, which encompasses the geology of NTS map sheets 75D and E, and parts of 85A and H, and 75C and D. It is based on Bostock's published and unpublished compilations, published figures in papers, primary field station data and geochronology, but does not incorporate geological data obtained by others during or

after his preliminary compilation, unless specifically sourced by Dr. Bostock's written notes. This synthesis is therefore a snapshot in geo-compilation time derived from robust primary field data collected in 1979-1981, 1983, 1985-1989, 1991, and 1997. It includes approximately 16,530 observational station sites, 17,500 rock type / lithologic descriptions, 26,000 structural and 500 kinematic indicator measurements, 11,400 samples, 2000 Pleistocene measurements and descriptions, 200 economic mineral observations, 200 radiometric measurements, and many metamorphic mineral counts. Laboratory analyses include representative lithology, silicate and ore petrology, mineral identification, geochemistry, paleo-magnetic determinations, and structural analysis of oriented samples. Dr. Bostock's then-futuristic computerized data compilations used standardized data entry (initially punch cards for a main frame computer) and form the timeless ground-truth information framework for this synthesis.

The maps span from west to east three major tectonic elements: the Taltson Magmatic Zone (TMZ), the Taltson-Rae Interface (T-RI) and isolated parts of the western Rae Province (Rae). The TMZ - T-RI contact is demarked by the sinistral Allan and Gagnon shear zones, the elongate Arch Lake and Gagnon granites, and the Berrigan Lake anorthositic complex. The TMZ comprises mainly north-south trending granitoid suites with infolds and folded enclaves of Rutledge paragneiss with minor metabasite. The granitoid suites include the western 1.986 Ga Deskenatlata granodiorite, a middle 1.955 Ga "Slave-type" monzogranite, which is in turn intruded by the central Konth batholith (1.937 Ga), several other late 1.938 -1.906 Ga granitoid rocks (Arch Lake, Natael, Othikethe Falls, Gagnon, and Benna Thy) and post-TMZ granitic bodies, a 1.882



Ga late Gagnon granite equigranular phase and a 1.813 Ga Thekulthili syenogranitic stock. Metasedimentary packages include the pervasive Rutledge River paragneiss which extends throughout the synthesis area and a lithologically similar unit, the Mama Moose paragneiss (distinguished by absence of tourmaline and graphite; youngest detrital zircon 2.08 Ga) which is confined to the eastern margin of the TMZ and may be allochthonous. Within the southern T-RI, the tectonically isolated north-south Hill Island metasedimentary package appears to be intruded by the also-tectonized 1.934 Ga Natael granite at the interface between the Taltson (west) and Nonacho (east) basement gneisses. In the northern T-RI the minimally metamorphosed but folded and faulted syntectonic Nonacho Group comprises three alluvial mega-cycles that rest unconformably upon fault blocks of the Nonacho (and locally Taltson) basement gneisses. The T-RI is intruded by 2.437 and 2.227 Ga early Rae granites, and the 2.340 Ga Thoa metagabbro. At the extreme western margin of the Deskenatlata granodiorite, a small exposure of presumed Paleoproterozoic, uncorrelated quartzite is flanked by Quaternary deposits.

## **AN ASSESSMENT OF PLANT PERFORMANCE AND MYCORRHIZAL INFECTIVITY IN SOILS COLLECTED FROM BAKER CREEK: A WATERSHED IMPACTED BY GIANT MINE**

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Giant Mine is an inactive gold mine located nine kilometers north of the Yellowknife city center. The Giant Mine remediation plan includes ecological restoration of Baker

Creek, a creek passing through the Giant Mine area, as one of its priorities.

The establishment and sustainability of diverse plant communities is in part dependent on the presence of arbuscular mycorrhizal fungi (AMF). AMF are beneficial soil dwelling fungi that form symbiotic associations within the roots of most vascular plants. Arsenic exposure, associated with mining activities, has been shown to reduce AM colonization, and growth of several plant species. Impaired plant growth and a reduction in AM colonization potential could impact plant establishment and community structure in Baker Creek. To assess the extent to which plants and mycorrhiza may have been impacted by Giant Mine, soils were collected from six sites along Baker Creek, two sites at nearby lakes, and a reference site at Yellowknife River. Seedlings of *Phalaris arundinacea* were grown in field-collected soils under growth room conditions. Plant growth and levels of AMF colonization were assessed after a 4-week period. Plant performance was greater in two of the three sites not receiving mine effluent; root length and shoot weight were significantly greater in seedlings grown in soils from Yellowknife River (the reference site) and Reach 7 (upstream from the mine) but not Pocket Lake. Roots had less than 5% mycorrhizal colonization at all sites except Yellowknife River and Reach 4, where colonization exceeded 20%. The higher levels of colonization at Reach 4 may be related to a realignment of the creek at this location in 2006; these soils have not been exposed to mine effluent for the 60-year span that other locations have experienced. A nutrient analysis of the soil did not yield any significant correlations with AMF colonization or plant growth however, arsenic levels were weakly correlated with plant and mycorrhizal performance.

**AN ASSESSMENT OF THE  
ACCURACY OF RADIOCARBON  
DATES FROM THE CENTRAL  
NORTHWEST TERRITORIES  
BASED ON THE OCCURRENCE  
OF THE A.D. 833-850 WHITE  
RIVER ASH IN POCKET LAKE,  
YELLOWKNIFE, NT**

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The Northwest Territories landscape is peppered by with innumerable lakes, whose sediment infill archives the Holocene environmental history of the region. Tracking environmental change over thousands of years permits determination of previous climate states, and rate of climate change through time. Proper interpretation of paleolimnological records requires precise chronological control, typically provided by <sup>14</sup>C radiocarbon dates and/or <sup>210</sup>Pb dating. Several potential problems have been identified with radiocarbon dates obtained in the region including: potential freshwater reservoir effects (FRE) that produce anomalously old dates, and low sedimentation rates which do not incorporate enough isotopes into the sediments, making measurements difficult or impossible. Recognition of a 3 mm thick tephra layer in Pocket Lake, located within Yellowknife city limits provides a potentially important aid for determining the nature of, and quantifying the scale, of any

possible radiocarbon dating anomalies. The shard morphology and major elemental geochemical signature of the tephra was used to identify the unit as the A.D. 833-850 White River Ash, produced by an eruption of Mt. Churchill, Alaska. In this presentation we discuss the implications that this finding will have on determining the accuracy of age-depth models derived from lake sediments in the region. Particular focus will be placed on an assessment of the impact of FRE on radiocarbon dating in the region, and whether there is any variability in FRE through time.

**VARIABILITY IN SOIL  
GEOCHEMISTRY IN THE  
YELLOWKNIFE REGION  
BEYOND MINE LEASE  
BOUNDARIES**

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The extent and characteristics of impact from ore processing activities, particularly roaster emissions deposited around the City of Yellowknife, are not well understood. This makes it difficult to define "natural" background conditions and gain a thorough understanding of the full effects of possible arsenic contamination. The cumulative influence of past mining and roasting activities prior to the collection of any geochemical baseline data makes defining the environmental impact of past land-use challenging. To assist in characterizing the extent of contamination caused by mining activities, regional scale data representative of potentially unimpacted and impacted areas has been collected in order to compare their differences in soil geochemistry.

Target areas for soil sampling were selected

based on their ease of accessibility, distance from the former Giant roaster, direction from the roaster with respect to prevailing wind direction, and location with respect to past or on-going research. Within each target area multiple sample sites were chosen with the primary goal of avoiding disturbed areas. Sample sites were selected based on the availability of various soil units, as well as the quality and quantity of soil at site.

Over a period of six weeks, 175 soil samples were collected from four primary units found throughout the region; outcrop soils, forested canopy soils, wetland soils, and peat. Where possible, core samples were obtained from each unit in a sample site. In areas where core samples were not feasible, grab samples were retrieved. Various soil types were investigated at each sample site to compare the degree of contamination between the different units.

Previous and ongoing research in the area has been focused on the extent and fate of arsenic and other mining-related contaminants in local lake waters and sediments. A regional-scale soil sampling initiative will complement previous geochemical surveys undertaken throughout the study area. This research will work towards understanding the connections between terrestrial and aquatic systems in the region by filling knowledge gaps in soil geochemistry and mineralogy. It is hoped that new tools and methodologies to differentiate between anthropogenic and natural forms of arsenic will also be developed and refined as a result of this work.

## **DOMINION DIAMOND JAY PROJECT INTEGRATED ENVIRONMENTAL ASSESSMENT AND DESIGN**

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When Dominion Diamond purchased the Ekati Diamond Mine in the Northwest Territories in 2013, it was scheduled to close in six years when existing resources were depleted. Dominion Diamond saw new potential in the Jay Pipe, but needed it to be developed economically and to produce ore by 2019, to avoid closing the mine. Golder Associates Ltd. helped Dominion Diamond develop an economic solution to extend the life of the mine, and provide an additional ten years of socio-economic benefits to Northern Canada through the development of the Jay Project.

The top of the Jay Pipe is located under approximately 5 to 10 m of overburden, on the lakebed in a water depth of approximately 35 m. To access the Jay Pipe, the surrounding area will be diked to allow it to be dewatered and the open pit to be developed “in the dry”. The dike is a leading concept of the project, comprising a length of over 5 km and an estimated volume of 5,000,000 m<sup>3</sup>. The environmental assessment (EA) of the Jay Project was also integrated with the design through the application of efficient and innovative methods. The aggressive schedule for the EA/Design Project meant that timelines needed to be compressed. Engineering and environmental teams collaborated

continuously as the project and environmental mitigation details evolved.

The Ekati Mine employs approximately 1,400 people, including 600 contractors, of which one-third are Aboriginal and over half are northern Northern residents. It is the largest Northern employer of Aboriginal people in the mining industry. Closure of the mine would result in a significant impact on employment in the Northwest Territories; the Jay Project will extend this employment by over a decade.

## **OVERVIEW OF SURFICIAL GEOLOGY ACTIVITIES IN THE TEHERY-WAGER GEM-2 RAE PROJECT AREA, NUNAVUT**

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Targeted field work during the summer of 2015 in the eastern part of the Tehery-Wager GEM-2 Rae Project area, mainland Nunavut, has provided an opportunity to gather data on the history and pattern of glacial flow and ice margin retreat, to collect till and stream sediment samples for provenance and mineral composition, and to test preliminary remote predictive mapping (RPM) surficial materials classification maps with field observations. The work was undertaken to provide new geological knowledge on the nature and composition of

surficial sediments deposited during previous glaciation(s), successive marine inundation and emergence, and addresses a number of scientific questions relevant to the mineral exploration industry.

The area between Wager Bay and Chesterfield Inlet is characterized by swaths of streamlined, thin and thick till extending southeast from the Keewatin Ice Divide zone centered in the uplands southwest of Wager Bay, which are dominated by a mixture of till deposits, felsenmeer and weathered bedrock. Along the central Wager Bay shores, early and late ice flows into and parallel to the bay are observed in the landform and striation record and suggest the ice divide extended in a narrow zone inland south of the bay. Till deposits are interspersed by a complex system of southeast-trending sub-glacial meltwater corridors and pro-glacial channels. These corridors comprise large eskers, outwash plains, small irregular hummocks, short streamlined landforms, eroded till remnants, boulder lags, and scoured bedrock. Continuous south-southeast-trending eskers, parallel to late striations, cross-cut the corridors and streamlined till in the central part of the region, and may be recessional features that formed after Daly Bay and Roes Welcome Sound became ice-free. The limit of marine submergence increases from ~119-125 m asl south of Wager Bay to about 138-152 m northwest of Daly Bay, as revealed by intensively wave-washed surfaces, wave-cut notches, bouldery deltas, high shorelines developed along esker flanks, and circular trimlines around small topographic highs. Marine sediment veneers occur as scattered deposits between rock ridges or glacial landforms in lowlands that skirt the coasts of Roes Welcome Sound and Chesterfield Inlet.

Bedrock samples were collected for

cosmogenic nuclide dating on weathered outcrops under the ice divide zone to constrain the relative age of potentially preserved (older) surfaces under a cold-based dome, and on wave-washed bedrock surfaces to date the timing of marine incursion and subsequent retreat. Marine shells were collected for radiocarbon age determinations to provide minimum deglaciation ages. Till and stream sediment samples were collected to help evaluate mineral potential near geochemical anomalies identified in 2012 as part of GEM-1, to characterize the regional glacial transport (provenance), and to support bedrock mapping in drift covered terrain. A preliminary surficial materials map was produced by classifying a combination of Landsat-8, Radarsat-2 C-HH and C-HV and DEM/slope data. Its accuracy is currently validated with the field observations and aerial photos that were gathered during the summer of 2015.

## **GEOPHYSICAL DATA PROJECTS 2015-2016**

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Geophysics is a subject of natural science concerned with the physical processes and physical properties of the Earth and its surrounding space environment. It is the analysis of nature as it pertains to Earth, its environment, and its structure. Geophysical methods are very beneficial and cost effective in the world of resource exploration. These methods enable surveying of large areas relatively quickly compared to other scientific techniques. Different geophysical techniques can be applied to solve complex problems. The more physical properties that are evaluated, the less ambiguous the interpretation becomes. Most geophysical methods are

non-invasive and environmentally friendly.

The Northwest Territories Geological Survey (NTGS) holds a large collection of industry and government geophysical data to which value will be added by re-analysis and interpretation. In addition, new geophysical data will be acquired over areas of high interest. The initial approach was to display the footprints of government-acquired aeromagnetic data available for the Northwest Territories on a map with associated link to download the data. Later, the footprints of industry-acquired aeromagnetic and other geophysical surveys will be added, and the archive of industry data will be enhanced by the generation of additional products.

The geophysical data submitted by industry in assessment reports is being enhanced and interpreted according to current industry standards and user friendly softwares. The enhanced geophysical products are first vertical derivative, second vertical derivative, analytical signal and magnetic susceptibility.

Aurora Geoscience Ltd. performed two types of geophysical survey for NTGS as part of the Slave Province Surficial Materials and Permafrost Study. These surveys were located approximately 25 km SE of Lac de Gras in the Northwest Territories, Canada. The Capacitive Coupled Resistivity survey was performed with 5m dipole length and Ground Penetrating Radar was performed with 50 MHz RTA antenna. The main objective for both geophysical surveys was to delineate the top of the bedrock for future exploration of kimberlite and economic mineralization.



## **GEM MACKENZIE PROJECT: PRELIMINARY SURFICIAL GEOLOGY MAP, WECHO RIVER, NTS 85-O, NWT**

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The Geo-mapping for Energy and Minerals (GEM) program of Natural Resources Canada provides a foundation for sustainable economic development in the North, and the Mackenzie Corridor region of interest represents the largest unmapped (bedrock and surficial geology) area of Northwest Territories. The goal of predictive surficial geology mapping is to develop timely first-version regional maps, validated in selected areas and reviewed by geological experts, which reasonably depict the distribution of basic or generalized surficial sediments, filling major knowledge gaps for northern industry exploration and development purposes.

The Wecho River map (NTS 85-O) identifies surficial geology and associated landforms resulting from the last glaciation (Wisconsinan), and from inundation about 13 000 cal BP by glacial Lake McConnell at the margin of the retreating Laurentide Ice Sheet. With continued falling lake levels due to differential isostatic uplift, the lake first separated from the Great Bear basin, and remained in existence until about 9500 cal BP, when the basins of Great Slave and Athabasca lakes separated. The resulting ancestral Great Slave Lake continued to decline, towards its present elevation of 156 m asl, constrained by the Mackenzie River outlet at Fort Providence.

This preliminary map of surficial geology is based on remote predictive mapping (RPM),

airphoto interpretation and fieldwork. The RPM methodology adopted for mapping NTS 85-O was based on the availability of remote sensing data and the authors' field experience of surficial materials and geology found in the region. The technique builds upon experience gained in previous surficial RPM activities in adjoining areas, 85-I, 85-J, 85-N, and 85-P. Preliminary results show that bedrock predominates in the land area throughout the map (69.7% of map area) and till veneer deposits become more prevalent in the northeast (12.6%). Undifferentiated till (1.2%) deposits, though limited in extent, are more common in the northwest. Glaciofluvial esker complexes generally form linear deposits trending southwest, and vary in extent (2.1%). Glaciolacustrine sediments (12.9%) are common in some lake and river drainage basin valleys up to 250 m elevation or more where they are fine-grained, whereas coarser-grained glaciolacustrine beaches and deltas occur as high as 330-350 m in the northeast, likely defining the eastern limit of glacial Lake McConnell. Remaining land area is comprised of wet organic deposits (1.5%) distributed throughout the map sheet. Results from 100 cross-validations using 75% randomly sampled data for training and the remaining 25% for validation indicate an average overall accuracy of the training areas of >97%. However, based upon comparison of mapping results with extensive field survey data, several glaciofluvial deposits were confused with bedrock. The final iteration of the map will involve some manual reclassification of the glaciofluvial class. Future work in 2016 will be the production of predictive surficial geology maps at 1:250,000 scale for NTS 85-O and NTS 85-K in the Canadian Geoscience Map (CGM) format.

## **HISTORIC CARIBOU TRAIL CLASSIFICATION USING GIS AND GROUND-BASED SURVEYS AT EKATI DIAMOND MINE**

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The digitization of caribou trails has been completed around the Ekati mine, Misery haul road, Lynx pit and the proposed Jay Project using orthophotos at a resolution of 1 hectare (1 ha; 100 m by 100 m) to identify areas of zero, low, medium and high occurrence of historical trails. A low use trail area was an area with five or less caribou trails, or trails covered less than 25 percent (%) of the orthophoto cell area (i.e., 100 m<sup>2</sup>). A medium trail area was classified as containing more than five trails but less than 15 trails, or trails that covered less than 50% of the cell area. A high use area had greater than 15 trails, or had trails that covered greater than 50% of the cell area.

A ground-based survey of historic caribou trails was completed along Misery Road from September 15 to 24, 2015. The objective of the survey was to ground-truth caribou trails that were visible on high resolution orthophotos with particular emphasis on cells where trails were not detected in orthophotos. The cells to be surveyed were randomly selected and a Golder biologist, two community assistants and Ekati Environment staff conducted the surveys. The field crew verified cell classifications on the ground by counting trails as well as habitat types that may limit the ability of historical trails to be detected (e.g., patches of boulder or bedrock). The information will be used to verify the accuracy of desktop-based trail classification

from orthophotos using GIS, assist in future trail digitizing and provide information about historic caribou movements through the Ekati mine area.

## **INTRA-LAKE ASSESSMENT OF THE UTILITY OF ARCELLININA (TESTATE AMOEBAE) AS BIO-MONITORS OF LACUSTRINE SYSTEM HEALTH IN FRAME LAKE, YELLOWKNIFE, NORTHWEST TERRITORIES, CANADA.**

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Frame Lake (FL) is a subarctic lake situated near the Yellowknife, Northwest Territories, city center. Prior to the early 1970s, the lake was considered to be a prominent city recreation area, as it supported a healthy fish population and, McNiven Beach was a well-known destination for swimmers on warm summer days. Through the years the water quality in FL deteriorated, first as a result of air fall of As and other metals of concern from mine operations in the years before proper diversion procedures were put in place. The physical dumping of mine tailing waste and sewage into the lake over a period of years further degraded the lake, capped off by the restriction in outflow from the lake subsequent to the construction of a causeway at the northeast end of the lake. Nutrification led to increased plant growth, oxygen depletion in winter and the eventual elimination of fish from the lake due to winter kill. The present-day lake bottom is

characterized by a highly contaminated and foul smelling sediment layer, locally up to 0.5 m thick.

Arcellinids, shelled protists that are sensitive to As contamination, and other proxies (e.g. trace elements, grain-size, loss-on-ignition and water nutrients) were analyzed in surface sediment samples (n=25) and freeze cores (n=2) collected from FL in September, 2014. Multivariate analysis of Arcellinina faunas in these samples has been crucial for identifying impacted sections of the lake and tracking the response of Arcellinina to temporal changes in lake conditions. Preliminary analysis results indicate that As levels in FL are high in surface sediment samples (median =270.8 ppm, max=1336.6 ppm, min= 145 ppm) and freeze cores subsamples (median= 159.7 ppm, max= 1538 ppm, min= 8.2 ppm). In addition, down-core analysis of arcellinids reveals a transition from low diversity, stress-indicating assemblages (centropyxid-dominated) deposited in contaminated surface layer sediments to a more diverse, healthy lake indicating assemblages in sediments deposited prior to the introduction of As contaminated sediment to the lake basin.

## **A NEW GEOLOGICAL COMPILATION OF BANKS ISLAND, NORTHWEST TERRITORIES – CHALLENGES, COMPLICATIONS AND CONTRIBUTIONS**

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The geology of Banks Island was mapped almost 40 years ago by A.D. Miall (GSC Memoir 387, 1974) and J-S. Vincent (Map

17-1979). Miall's field mapping and well core analysis of stratigraphy and sedimentology was published in two GSC memoirs and five maps at 1: 1 000 000 and 1:250 000 scales. Vincent mapped Quaternary deposits, but included considerable detail about bedrock units in two maps at 1:250 000 scale. Until now, these data were not integrated into a comprehensive bedrock geology map of the island.

This integration was challenging as previous geological mapping was done with reference to geographic features, not reference grids. Topographic maps have been refined since this data were plotted on the then current base maps, thus altering the form and location of geographic features referred to by the mappers. Additionally, standard UTM coordinates have changed from NAD27 to NAD 83. Moreover, images of scanned paper maps are distorted and digital cartography permits much attention to details of geological contacts and their interplay with topography. These factors meant that every original mapped contact had to be repositioned and redrawn.

The strata of Banks Island are divided into four, primarily clastic successions bounded by unconformities. The Neoproterozoic Rae Group is part of the larger sequence shed from the Grenville Orogen and was intruded by the Franklin Magmatic Suite. Paleozoic carbonates of the Arctic Platform are present only in the subsurface. The Devonian clastic wedge was shed from the Ellesmerian Orogen. The Cretaceous clastic wedge originated from the Laramide Orogen, and passes upward into the Eureka Sound Group of Paleogene age derived from the Eureka Orogen. Finally, extensive fluvial systems created the Miocene Beaufort Formation which was deposited on a gently west-dipping, incised plateau whose drainage

system mimics the Holocene to Recent topography.

Gentle deformation and uplift took place between all successions. Open folds and normal faults of small displacements produced only shallow dips of most strata. Thus topography is a reliable guide for the interpretation of depositional contacts under glacial and recent deposits once the geometries of the bounding unconformities are understood. The NeoProterozoic-Cretaceous unconformity is restricted to southern Banks Island and is well constrained by outcrop data, as are its extensions to the east where gently-dipping Devonian strata lie beneath it. The continental deposits of the Beaufort Formation, however, lie on a surface of considerable relief whose contours were determined by noting elevations of exposures mapped in numerous localities primarily by Vincent. Relationships among several glacial units and Beaufort strata allowed extrapolation of the latter in most areas, constrained by the intersection of the basal unconformity with present topography. Reworking of Beaufort strata in many areas by fluvio-glacial processes was assumed to have not totally removed them.

The resulting map revealed a greater extent of Beaufort Formation outliers across the western two thirds of Banks Island than previously mapped and refined the distribution of all older units. This map nonetheless stands as a tribute to the meticulous work of Miall and Vincent in gathering and interpreting the original data.

## WHAT IS NEW FOR SEDEX DEPOSITS OF THE CANADIAN CORDILLERA?

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Recent TGI4 research activities on SEDEX deposits in the Selwyn and Purcell basins of the Canadian Cordillera provide new ideas on the genesis of SEDEX and innovative techniques to better understand, model, and detect buried mineral deposits. Activities focussed on: 1) Establishing the physico-geochemical processes of the hydrothermal system; 2) developing new mineralogical, geochemical, and isotopic tools toward vector to SEDEX mineralization; 3) understanding processes that control surficial geochemical dispersion of metals around deposits; and 4) developing new methods for regional-scale 3D geological modelling in sedimentary basins. Key findings are:

SEDEX deposits formed in settings with dynamic redox fronts controlling sulphide and sulphate precipitation within carbonaceous sediments. Zinc, Pb, Cu and other metals are leached from deeply buried clastic sediments during metamorphic mineralogical transformations driven by

increasing temperature and pressure during burial. Close proximity to a carbonate platform was an important requirement for the mineralizing systems, enhancing access to sources for saline, metal complexing brines.

At the Howard's Pass (HP) deposits (Yukon), sulphides precipitated from dense bottom-hugging metalliferous brines that accumulated in a bathymetric low, distal to vent complex(es), and percolated into porous unconsolidated sulphidic carbonaceous muds. At the MacMillan Pass (MP) deposits (Yukon), hydrothermal sulphides precipitated sub-seafloor due to interaction of hot (>250°C), acidic (pH = 4.5) metal-bearing hydrothermal fluids with H<sub>2</sub>S generated during a number of processes (bacterial and thermochemical sulphate reduction, barite dissolution, and sulphate reduction coupled with anaerobic methane oxidation) in the carbonaceous mudstones. At HP and MP, most of the Zn-Pb mineralization was precipitated below the seafloor as replacement of early barite (at MP) and fine-grained sediments (at HP and MP) during early diagenesis.

At HP, the Active member of the Duo Lake Formation, host of the Zn-Pb mineralization, shows a weak spectral response in visible-near infrared and short wave infrared spectroscopy (VNIR-SWIR), except within and adjacent to significant mineralization. A similar pattern occurs at MP, where siderite, muscovite, phengite and montmorillonite are spectrally identified within the feeder zone of the Tom Pb-Zn-Ba deposit.

Micro (laser-assisted fluorination) sulphur isotopes analyses of sulphides at the Prairie Creek deposit (NT) reveal temperature gradients within the main stratabound massive sulphide lens, with hotter

temperatures closer to the center of the lens and the vein system.

In an under-explored embayment of the Selwyn Basin in NT, carbon isotope stratigraphy and whole-rock geochemistry identified a hitherto unrecognised mid-Cambrian metalliferous black shale that may be equivalent to host rocks of the past-producing Anvil district (YT).

Methods developed for 3D geological modelling of the Purcell Basin and Sullivan Pb-Zn-Ag deposit (BC) enable the objective estimation of the 3D geological framework for future multi-scale SEDEX system characterization. Combined mine and regional scale studies can benefit from these new 3D integration and modelling approaches for developing basin architecture models for proximal and distal indications of SEDEX deposits (e.g., synsedimentary faults, sub-basins, cryptic geophysical response, geochemical dispersal patterns, magnetic anomalies of structures, etc.), and thereby increase the potential for deep discovery. Results offer a new perspective on geology that may lead to new approaches in exploration.

## **RELATIONSHIP BETWEEN FOREST STRUCTURE AND NEAR-SURFACE GROUND ICE CONDITIONS, NORTH SLAVE REGION, NWT**

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Climate warming or disturbance can thaw near-surface permafrost causing surface subsidence in areas where ground is ice-rich.



Permafrost thaw can also lead to the alteration of entire ecosystems by releasing water stored as ice, disrupting groundwater flow pathways, and causing soil disturbances and mass wasting. Terrain subsidence can also damage infrastructure and affect the well-being of people living in areas underlain by permafrost. There has been some work to model the distribution of ground ice in areas of discontinuous permafrost. However, there have been few in situ studies in mineral soils of the boreal forest, which compare the relative importance of several factors that influence ground ice content. This field study was conducted to examine the relationship between biophysical factors and the occurrence of segregated ground ice in permafrost underlying subarctic forest in the North Slave region of the Northwest Territories.

The objective of this research is to gain a better understanding of the ecological drivers of ground ice in boreal forests with fine-grained mineral soil. To meet this objective, data were collected at 20 sites to sample the gradient of ecological succession for two main forest types: black spruce, and white spruce/white birch. At each site, micro- and meso-topography (hummock size, slope, and elevation), active layer, forest structure (forest composition and structure), and ground vegetation composition was measured. At each site, 26 to 32 cores were obtained (3 to 4 boreholes) to quantify ground ice content in the top 1 m of permafrost.

Preliminary results suggest an increase in permafrost ground ice content as the forest progresses in its ecological succession, with older forests having thinner active layers, developed ground cover, and greater canopy cover. Black spruce forests have greater micro-topographical relief in older stages,

whereas white spruce/white birch forests remain relatively flat throughout all stages.

In addition, the data suggest white spruce/white birch forests are more ice-rich in the near-surface permafrost than black spruce forests. However, ice content is more variable under white spruce/white birch forests than black spruce forests. These results have applications for larger scale efforts to map near surface ground ice from vegetation characteristics.

## LASER SCANNING ISSUES ON TUNDRA AND MAN-MADE SURFACES

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With industrial development underlain by permafrost and/or rising global temperatures, there is an increasing chance of the degradation of permafrost. Few methods currently exist to accurately quantify ground subsidence related to the thaw of permafrost with surveying equipment and terrestrial laser scanners (TLS). With modern technologies it is possible to measure smooth surfaces (e.g., a road) within a few millimeters of accuracy, however, in the natural environment it is not so simple. Vegetation, or any material that is known as a surface cover, can interfere with the accuracy of the actual surface. Due to this nature, the definition of a surface is not well defined for natural environments.

A Leica MultiStation (MS50) was used to survey many locations in the Slave Province and around Yellowknife (Northwest Territories) during the summer of 2015 (June-August). The results (point clouds) from the MS50 give an x, y, and z coordinate of the point. The given results

produce the elevation (z coordinate), which can give an accurate representation of the surface. However, LiDAR is affected essentially by four main factors: the geometry, instrumental effects, target scattering characteristics, and atmospheric effects. The geometry and the target scattering characteristics will be focused on. The geometry deals with the incident angle. In general it is assumed that the lower the incident angle is the higher the accuracy, which is hard to achieve in the natural environment, with the use of a TLS. The target scattering characteristics are characteristics of the targeted surface (e.g., the irregularity of the surface or reflectance) that do not follow the Lambertian scattering law.

The primary objective of this study will be to build on other experiments that have been conducted (e.g., Kaasalainen, S., et al, 2011; Soudarissanane, S., et al, 2007; Kaasalainen, S., et al, 2005) to search for correction methods. The use of the computer programming language Python will be used in order to calculate the accuracy of the z coordinate. The goal of this research is to determine how strongly the measured elevation of a surface is affected by variations in incidence angle and distance of the scan, as well as how the variations are related to the roughness of the target surface. With the proposal of this research a better understanding of the incidence angle and backscattering (referring to the direction of the scattering of the particle) will come to be, and as such a better understanding of a surface in the natural environment.

## UNRAVELLING THE KINEMATIC HISTORY OF THE MARCH FAULT, NAHANNI REGION, NWT

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The present structural model for mineralized strata of the Howard's Pass Pb-Zn district holds that deformation was largely syndepositional and Silurian in age, and was later overprinted by deformation related to the Mesozoic accretion of the pericratonic Yukon-Tanana terrane. Recent work has led to the proposal of a new, postdepositional structural model for the strata of the Selwyn Basin and mineralization in the region. The March Fault, a high-angle, northeast-verging thrust fault that cuts broadly parallel to folded Selwyn Basin stratigraphy to the south and east of the Howard's Pass district, is a component of this revised structural model; however, the role of the March Fault with respect to the structural geometry at Howard's Pass and to its potential controls on the distribution of mineralization is poorly understood. Detailed structural analysis of the March Fault and associated penetrative deformation will provide an improved structural context for further exploration at the Howard's Pass district and other Zn-Pb & Va occurrences to the southeast.

A M.Sc. project was created in spring 2015 to address the structural geometry of the March Fault and its relationship to regional ductile deformation in the vicinity of Howard's Pass. The goals for the first season were to (1) improve our understanding of the local stratigraphic succession, (2) acquire and interpret outcrop-scale structural

data, and (3) collect samples representative of both stratigraphy and structure for lithological and fabric analysis. Three zones along the March Fault, southeast of the Howard's Pass district, were selected for 1:7500 scale mapping based on previously identified structural and stratigraphic complexity. Initial observations suggest that regional stratigraphy conforms to previous interpretations (e.g. Green, L.H., Roddick, J.A., and Blusson, S.L. 1968. *Geology, Nahanni, District of Mackenzie and Yukon Territory*; Geological Survey of Canada, Map 8-1967). One main northwest-trending foliation (Sm) was identified across all mapping areas; this foliation is axial planar to centimeter- to meter-scale, tight to isoclinal folds. Locally, intersection lineations of secondary folia that crenulate Sm trend northwest-southeast and have variable plunge. Other key structural features identified include local transposition of bedding into foliation planes, rootless folds of bedding, boudinaged bedding layers, refolded folds, and pressure-solution. Metamorphism is variable and ranges from friable, coarse grained marble and low-grade, lustrous phyllite, to coarser grained, micaceous schist with andalusite and possibly cordierite porphyroblasts. Overall, the preliminary map pattern suggests lithological repetition by folding, and older-over-younger juxtaposition of strata by thrusting. A significant portion of strain was accommodated by volume loss and mass transfer through development of penetrative folia.

## RECONNAISSANCE MAPPING, STRATIGRAPHY AND MAGNETOTELLURIC SURVEY OF THE BROCK INLIER, NORTHWEST TERRITORIES

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Our studies of Brock Inlier comprise an activity within the GEM2 Mackenzie project's Shield to Selwyn geo-transect: studying the evolution of sedimentary rocks of the northern mainland NWT to improve exploration success. The Brock Inlier, an uplifted region of mostly early Neoproterozoic sedimentary rocks surrounded by lower Paleozoic and Cretaceous sedimentary rocks, is located just east of Darnley Bay, Northwest Territories. It overlies the eastern edge of the Darnley Bay anomaly, said to be the largest known gravity and magnetic anomaly in North America. Preliminary responses from 17 magnetotelluric survey stations along an E-W profile over the anomaly indicate that the overall thickness of the sedimentary succession above it is considerably greater along the western portion of the profile and suggest a conductive feature in the vicinity of the known anomaly. Our stratigraphic work has documented the first complete detailed record of early Neoproterozoic Shaler Supergroup and Cambrian-Ordovician Mt Clark, Mt. Cap and Franklin Mountain formations; sandstone, shale and carbonate rocks exposed along the Hornaday River. Samples of these rocks have been

collected for paleontological, geochronological and geochemical analysis. Helicopter-supported regional geological reconnaissance and selected ground traverses in key areas of NTS 97A (Erly Lake) allowed us to recognize inconsistencies in previous mapping and will help us to build new and improved geological maps. This work will be aided by analysis of newly acquired, high resolution remotely sensed and video imagery.

## **EXSHAW FORMATION STUDY – LIARD BASIN, NORTHWEST TERRITORIES, CANADA**

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The Liard Basin covers an area of 8,400 sq. km and straddles the Northwest Territories (NT), northeastern British Columbia (NEBC), and the Yukon (YK) borders. Unconventional shale gas exploration was first initiated in the NEBC portion of the Liard Basin in approximately 2009 where the exploration focus was on the organic rich, black shale of the Exshaw Formation (Fm.) A tri-jurisdictional resource assessment of the Exshaw Fm. in the Liard Basin was initiated in 2015 by the Northwest Territories Geological Survey (NTGS), the BC Ministry of Natural Gas Development, the National Energy Board (NEB) and the Yukon Geological Survey (YGS). The purpose of this paper is to present the results of the NTGS study of the Exshaw Fm. in the NT portion of the Liard basin.

The Exshaw Fm. stratigraphy was established using core and logs from the Patry b-23-K well as outlined by Ferri and others in the BC Ministry of Natural Gas' 2015 Oil and Gas Geoscience Reports. In

BC, this interval is comprised of three units: Upper Exshaw, Lower Exshaw and the Patry. Regional cross sections were constructed and tied to the Patry b-23-K well to establish a stratigraphic framework for the Exshaw Fm. throughout the study area. A comprehensive suite of maps and data were compiled for the resource assessment. These include the following: depth of formation, gross and net shale isopachs (using a 10 %m cut-off) and bottom-hole temperature. Calculated parameters that were not mapped include wt% TOC, estimated temperature and pressure gradients.

In the NT part of Liard Basin, the Exshaw Fm. is up to 303m thick and averages 3.35% TOC. In general, it is thickest to the south near the BC border and thins northwards. The isopach also thins dramatically at the Bovie Structure, the easternmost extent of Liard Basin. Using the aforementioned resistivity cut-off, net pay is up to 270m thick. The Patry member can be correlated into the Northwest Territories as far as 60.6°N. At Bovie Structure it is absent and is considered to correlate with part or all of the Kotcho Formation. The average temperature and pressure gradients are 0.0411°C/m and 8.81kPa/m, respectively.

## SPATIAL VARIATIONS IN ARSENIC GEOCHEMISTRY IN SEDIMENTS AND THEIR ASSOCIATED POREWATERS FROM LAKES IN THE YELLOWKNIFE REGION

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Long Lake and Martin Lake are both located approximately 5 km downwind from the former roaster at Giant Mine; as such, these lakes may have received roaster emissions. In Long Lake, a sediment survey was conducted to determine how sediment arsenic concentrations vary spatially and with depth. In both lakes, sediment cores were extracted from shallow- and deep-water sites to capture vertical variations in sediment chemistry and to identify arsenic-rich intervals. Additionally, peepers were installed at the shallow-water sites to capture vertical variations in sediment porewater chemistry. Element concentrations in both the sediments and porewaters were analyzed. Polished sections of sediments were examined using scanning electron microscopy to identify arsenic-hosting phases at select sediment intervals.

The sediment survey in Long Lake indicates that sediment arsenic concentrations are highest in deep-water sediments (>1000 mg/kg) and are lowest in the beach area located at the eastern end of the lake (9 mg/kg). These values are elevated when compared to the arsenic interim sediment quality guideline of 5.9 mg/kg outlined by the Canadian Council of Ministers of the Environment (CCME). In the deep-water core from Long Lake, two peaks in sediment

arsenic concentrations were identified: a peak of 1000 mg/kg occurring at 3.5 cm below the sediment water interface (SWI) and a peak of 1500 mg/kg at 18 cm below the SWI. At the Martin Lake deep-water site, only one maximum of 560 mg/kg was observed, occurring at 25 cm below the SWI. Maximum arsenic concentrations of 90 mg/kg and 430 mg/kg were observed at 0.5 cm below the SWI at the shallow-water sites in Long Lake and Martin Lake respectively. The analysis of sediment porewaters from the shallow-water sites indicates that maximum arsenic concentrations occur several centimetres below the maximum arsenic concentrations observed in the sediments.

Arsenic trioxide grains were identified by scanning electron microscopy in samples from both lakes and likely originate from roaster stack emissions. In the shallow-water site at Long Lake, oxides containing aluminum, iron, and manganese were found to be the dominant hosts of arsenic in the upper 2 cm of sediments. Below this interval no arsenic-hosting phases were observed. In contrast, the deep-water site is characterized by the presence of arsenic-sulphides. In the shallow-water site at Martin Lake, arsenic-sulphide was identified and the relative proportion of this phase appears to increase with depth.

Our initial results are interpreted to reflect spatial variations in sedimentation and local redox chemistry. However, additional work is necessary in order to accurately determine the extent and nature of roaster impact in both Long Lake and Martin Lake.



**CAMERA TRAPS AS A  
MONITORING TOOL FOR  
LARGE MAMMALS AT  
INDUSTRIAL SITES IN THE  
CANADIAN ARCTIC –  
STRENGTHS AND  
WEAKNESSES**

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Camera traps are becoming increasingly popular as a monitoring tool for large mammals at industrial sites. Cameras are a cost effective and low maintenance passive sampling technique, but few studies have been conducted with them in Arctic environments. During the last five years, we have tested the use of camera traps in tundra environments of the Northwest Territories and Nunavut at six locations, using >400 cameras. We report on the strengths and weaknesses of this monitoring method through featured analyses to examine the timing of wildlife movement, habitat selection, distribution of wildlife groups and collaboration with holders of Traditional Knowledge. We also discuss methodological issues of effort, habitat selection, capture probability, sample size, and deployment. We conclude that cameras can be an effective tool for monitoring wildlife for a sub-set of wildlife questions.

**A VALIDATION OF  
HYDROACOUSTIC SURVEYS  
FOR FISH IN SMALL ARCTIC  
LAKES**

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The use of transmitted underwater sound for describing aquatic resources (known as hydroacoustics) has an extensive record of successful applications in fisheries management. Projects with large aquatic footprints or those with complex regulatory considerations may benefit greatly from this technology. The approach provides a non-lethal alternative to standard fish sampling methods and can provide a cost-effective means for collecting large volumes of data (such as fish abundance estimates) over large areas within a short-window of opportunity afforded by project schedules in the Arctic. However, the application of hydroacoustics in the North is relatively new, with most of the current standards for the technology having been established in Great Lakes and ocean environments. Dominion Diamond's Lynx Project provided a unique opportunity to assess the validity of the hydroacoustic approach for estimating population sizes and biomass of fish in a small Arctic lake. Multiple surveys of Lynx Lake were performed using an echosounder unit with horizontal and vertical-beaming transducers mounted on a small boat in early summer 2015, which preceded a fish-out of Lynx Lake later that summer using standard fishing methods. The fish-out was evaluated in two phases, where the first relied exclusively on the use of gill net sets, and the second on a suite of sampling gear types.

Hydroacoustic predictions of single fish targets ranged from 310 to 463 fish across surveys, versus 396 fish captured during phase 1 of the fish-out (most of which were Lake Whitefish), and 625 fish during phase 1 and phase 2 combined. Hydroacoustic predictions of biomass ranged from 122 to 181 kg biomass across surveys, versus 188 kg of biomass captured during phase 1 of the fish-out, and 221 kg of biomass captured during phase 1 and 2 combined. The results suggest that although multiple surveys of a lake are recommended, hydroacoustics can provide a reliable prediction of abundance and biomass for species that exhibit pelagic-like behavior. Hydroacoustics can also provide a reasonable approximation of total fish biomass in lakes characterized by a Lake Whitefish dominant species assemblage.

**QUANTITATIVE  
PALYNOLOGICAL ANALYSES  
OF ALBIAN-CENOMANIAN  
(LOWER TO UPPER  
CRETACEOUS) STRATA IN THE  
SVERDRUP BASIN: INSIGHTS  
INTO PALEOECOLOGY,  
PALEOCLIMATOLOGY AND  
PALYNOSTRATIGRAPHY**

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Multivariate statistical analyses of terrestrial palynomorphs from Albian to Cenomanian (Lower to Upper Cretaceous), Sverdrup Basin strata reveal a landscape with wet lowlands inhabited by Pteridophytina and Bryophyta, with cooler, moist uplands inhabited by a variety of conifer plants. A humid and temperate climate prevailed at this time. Three sites from eastern Sverdrup Basin contain similar palynofloras with

long-ranging taxa, but quantitative palynological analyses reveal important differences in relative abundances between localities. A total of eleven early angiosperm pollen were recovered, providing further evidence of a delay in the dispersal and diversification of angiosperms into the Sverdrup Basin relative to more southern locations. This latitudinal diachroneity may potentially be due to paleogeographic barriers, such as, the Arctic Ocean, the extent of the Western Interior Seaway, or due to limited insect pollination dispersal strategies.

**USING PALEOLIMNOLOGY TO  
ESTABLISH BASELINE  
SEDIMENT METAL  
CONCENTRATIONS AND TO  
RECONSTRUCT  
HYDROECOLOGICAL  
CONDITIONS, MARIAN RIVER  
WATERSHED, NWT.**

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Formed in 2005 with the signing of the Tłıchq Agreement, Tłıchq Lands occupy an area of approximately 39000 km<sup>2</sup> in the central Northwest Territories between Great Slave and Great Bear lakes. The Marian Watershed Stewardship Program (MWSP), established in 2013, is designed to assess and monitor areas within the Marian River watershed important to traditional fishing and livelihoods. The program aims to assess ecosystem health through monitoring and

sampling of water, sediment, and fish throughout the Marian River watershed. Of particular concern is the proposed NICO mine and the potential for cumulative effects of development, land disturbance, and climate change in the Marian River watershed. While water and sediment quality monitoring in areas of industrial developments is an integral part of water management programs to ensure protection of ecosystems, absence of long-term measurements can make it challenging to define reference conditions effectively. As a contribution to the MWSP, this research uses paleolimnological approaches to establish baseline sediment metal concentrations in lakes and to reconstruct past hydroecological conditions. During late summer 2015, sediment cores were obtained using a gravity corer from several lakes within the Marian River watershed and sectioned at 0.5-cm intervals. Sediment sub-samples will be analyzed for a suite of radiometric ( $^{210}\text{Pb}$ ,  $^{137}\text{Cs}$ ), physical (loss-on-ignition), and geochemical (organic carbon and nitrogen elemental and isotope composition, cellulose oxygen isotope composition) parameters, and biota (diatoms, pigments), as well as metal concentrations. The hydroecological reconstructions will place recent observations of low water conditions into a longer temporal context needed to assess potential causes, and provide knowledge to interpret stratigraphic patterns and trends in the metal concentration data, as has been demonstrated elsewhere (Wiklund et al. 2012 *Science of the Total Environment* Wiklund et al. 2014 *Environmental Research Letters*). Results will provide measurements of pre-development reference sediment quality conditions that can be utilized to assess for evidence of pollution based on collection and analysis of lake surface sediments deposited after the NICO

mine becomes operational as well as other potential future industrial developments.

## **THE MOBILITY OF ARSENIC IN SEDIMENTS AND CO-EXISTING PORE WATERS FROM THREE SMALL LAKES WEST OF GIANT MINE, NWT**

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The purpose of this study is to determine whether the arsenic present in three lakes proximal to Giant Mine 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. The approach was to assess the speciation of arsenic in both lake sediments and associated porewaters using dialysis arrays, major and trace elements analysis, age dating of sediments, synchrotron-based analysis, and advanced scanning electron microscopy. Results from these analyses can help us characterize arsenic species, and their relative stability, and thus estimate the long term fate of arsenic in the aquatic environment, which is an important component in understanding current and future ecological and human health risk.

Field programs were completed in July 2014 and April 2015. Three lakes within 3 km of the historic roaster stacks were sampled representing a range of physical and chemical properties. The study lakes differed in size, depth, catchment area, catchment vegetation, and hydraulic connectivity to other lakes. Preliminary results from summer samples show a range of arsenic phases contained in lake sediments, including arsenic trioxide and arsenic sulphides. The occurrence of arsenic trioxide in the sediment column correlates with the beginning of industrial operations

in the region. Peak arsenic concentrations in sediments commonly occur in the top 10cm, between 700 and 1100ppm. Iron-free arsenic sulphides are predominantly associated with framboidal pyrite, suggesting that they are re-precipitation products, and that some of the arsenic in porewaters is captured in sediments in this form. Arsenic concentrations in sediment porewaters consistently peak 2-6 centimeters below the sediment-water interface at concentrations between 200 and 1200ppb, indicating a trend of remobilization of unstable arsenic species and migration through the sediment column. Results from the winter sampling program are at the time of writing incomplete and will therefore not be presented at the Geoscience Forum.

Understanding the sources and behaviour of arsenic in these small lakes is important since First Nations and other local people have traditionally used the area for hunting and fishing as well as recreational purposes. Information such as this will ensure that future ecological and human health risk assessments accurately reflect conditions in the field.

## **MINE TO MICRON: SYNCHROTRON SCIENCE FOR MINERAL EXPLORATION, PRODUCTION, AND REMEDICATION**

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Synchrotron science for mineral exploration, production, and remediation studies is a novel niche presently under utilized in our field. Harnessing synchrotron light for micron-scale analysis provides a powerful

tool that addresses industry relevant problems using a rapid high-resolution analytical technique. Synchrotron micro X-ray fluorescence (uXRF) provides quick and effective micron-scale trace element analysis and mapping of ore minerals with ppm detection limits. Speciation of trace elements can also be probed using X-ray absorption near-edge structure (XANES) spectroscopy.

uXRF mapping and XANES analysis of pyrite grains associated with gold from deposits in the prolific Timmins and Kirkland Lake gold camps has been undertaken to address questions regarding mineralization history and develop novel trace element exploration vectors. This information provides integral insights into trace element associations with ore minerals, local redox conditions responsible for mineralization, and mineralizing mechanisms.

Gold is commonly intimately associated with pyrite mineralization and is present both as inclusions and fills fractures in pyrite grains. Gold may also occur as nanoparticles and/or in the pyrite crystal lattice; known as “invisible gold”. Understanding the nature and distribution of invisible gold in ore is integral to processing efficiency. Lattice bound refractory gold cannot be liberated by conventional cyanide and carbon absorption processes, and can exist in concentrations up the weight percent level in arsenian pyrites. The high flux and energy of a synchrotron light source allows for the detection of invisible gold by uXRF, and can probe its nature (metallic Au<sup>0</sup> vs. lattice bound Au<sup>1+</sup>) using XANES spectroscopy.

Tailings management facilities (TMFs) play a critical role in reducing the environmental impact of mining operations. As part of regulatory compliance process it is

important to determine which minerals are present in the TMF and how they evolve over time. XANES spectroscopy is an excellent tool for determining arsenic speciation. Mineral phases such as scorodite, gersdorffite, arsenic oxide, and poorly crystalline FeAsO<sub>4</sub> can all be accurately identified as well as relative amounts determined. With this information the oxidation-reduction of As bearing compounds can be monitored and effective management practices put in place to ensure long-term capture of toxic phases.

## **THE INDUSTRIAL MINERAL INVENTORY OF THE NORTHWEST TERRITORIES**

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Industrial Mineral production in Canada in 2014 amounted to over \$16 billion, including \$1.8 billion in the Northwest Territories. This represents approximately 20 times the value of metallic mineral production in the territory.

The majority of industrial mineral production in the NWT is of diamonds. Diamonds are traditionally included in industrial minerals statistics since they are a source of abrasives and gemstones, both of which are considered industrial minerals. Smaller amounts of stone and aggregates are also produced at this time. The requirements for stone and aggregates will increase in the future as infrastructure needs grow within the Territory. The potential exists, however, for the production of a number of additional commodities, several of which have been the subject of resource assessments to date.

Silica resources have been evaluated in the South-central portion of the NWT, with a

report (NWT Open Report 2014-002) now available. Silica sand meeting industry specifications was identified in several locations. Possible uses for this material include frac sand, glass manufacture, and other uses requiring high silica content.

Limestone along the Hay River – Enterprise – Kakisa corridor was also examined with a preliminary report (NWT Open Report 2010-007) available, and a follow-up report (NWT Open Report 2015-001) in the final stages of preparation. High calcium limestone, limestone and dolomite resources are identified. These resources meet requirements for such diverse uses as mineral fillers, water treatment, mine tailings treatment, and agricultural lime, among others.

A poster presentation at the Geoscience Forum in 2009, identified potential sources of dimension stone (granite, slate and limestone) in the Yellowknife – Behchoko area.

Most recently, a preliminary survey was conducted of potential salt sources within the Territory.

Additional industrial mineral occurrences (mica, pegmatite minerals, barite, fluorite, etc) are known within the NWT, but have not been investigated to date.



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