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Dipping Devonian strata outcropping along Little Doctor Lake, Northwest Territories.

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Hydrothermal and structural controls on lead-zinc mineralization at Pine Point, Northwest Territories

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The Pine Point Lead-Zinc camp has historically been classified as “MVT-Type”. Wide-spread lead and zinc mineralization is localized into some 100 deposits over a 72-kilometre trend. Data from roughly 20,000 historical drill holes (1945-2012) have been recovered and converted to a modern digital database and tied into GIS space using LiDAR and DGPS. Field observations and 1326 new drill holes are combined with new airborne gravity gradiometry and airborne magnetic surveys. Ground-based IP and gravity surveys provide further geophysical precision and petrological microscopy, pXRF and μ XRF provide new mineralogical detail. These datasets have been modeled in 3D at a regional and deposit scale.

Pine Point deposits are characterized as “Tabular” and “Prismatic” types. Tabular deposits are elongated, with a strata-bound preference to mineralization. Prismatic deposits are characterized by a vertical aspect, often crosscutting multiple stratigraphic units. Both types exhibit sulphide-mineral zonation. Mineralization is hosted in dolomite-altered, lower Devonian carbonate reef and platform carbonates, with the Great Slave Shear Zone, a deep-crustal structure, obliquely transecting Pine Point.

Early-stage dissolution of primary carbonates and precipitation of secondary dolomite alteration was developed by low-temperature hydrothermal fluids. Alteration shows preference for specific facies within the reef, but new evidence also suggests significant structural controls. Sphalerite, galena, and marcasite mineralization is associated with on-going dissolution and alteration. Alteration is characterized by various textures and stages of hydrothermal dolomitization, some of which are pathfinders to mineralization, and calcification. Hydrocarbons (bitumen, H₂S) present during precipitation of sulphide minerals may have provided a source of sulphur and played a key role in the precipitation process.

It is now demonstrated that the Tabular deposits form as discrete channel ways with significant structural influence as demonstrated by stratigraphic off-sets and vertical fracturing in drill core. These channel ways feed directly into the Prismatic-style deposits where the combination of lithology and fracturing maintained fluid focus and promoted vertical fluid flow and resultant mineralization with related alteration.

On-going, paleo-dissolution and reprecipitation during the mineralizing process is demonstrated by stratified sedimentary rock consisting of non-soluble material and, locally, sulphide detritus within paleo-cavities. The system was active during and after this internal sedimentation as demonstrated by the development of colloform sphalerite growing within these internal sedimentary rocks. Recent karst, is characterized by till-filled collapse structures unrelated to mineralization.

We classify these deposits as “Carbonate Hosted Pb-Zn” demonstrating structural and stratigraphic control of low temperature hydrothermal alteration and resultant mineralization in the presence of hydrocarbons.

Characterization of permafrost cores along the Inuvik–Tuktoyaktuk corridor

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In order to understand permafrost and paleoenvironmental conditions near the newly developed Inuvik-Tuktoyaktuk Highway (ITH), Northwest Territories, permafrost cores were collected in the winter of 2017 by the Northwest Territories Geological Survey and partners as part of the Sentinel Drilling program. This study analyzed five cores (BH-1, BH-2, BH-3, BH-4, and BH-8) situated within hilltops, riparian, and peatland terrains, recording various depositional environments.

Cores were analyzed for cryostructures, water isotopes ($\delta^{18}\text{O}$ and $\delta^2\text{H}$) and underwent radiocarbon dating to determine the origin of the sedimentary records and associated ground ice.

Collectively, these results indicate that deposits within low-relief areas (such as peatlands and riparian zones) are characterized by hosting ice with enriched values, similar to modern-day, local isotopic composition, *i.e.*, local precipitation values. BH-1, BH-3, and BH-4 all had an ice-poor diamict present at depth. The ice within these diamicts ranged from $\delta^{18}\text{O}$ -23‰ to -19‰, with a co-isotope slope lower than the local meteoric water line; indicative of thawing during the Early Holocene warming, followed by subsequent stabilization and permafrost aggradation.

Core BH-8 contained a fine-grained unit, with laminations, overlain by ~ 4 m of peat. Radiocarbon dates and sedimentary structures indicate a shifting landscape with a local lake from ~11,500 to 9000 years ago, subsequently draining, developing epigenetic permafrost, and transitioning to syngenetic peat in the early Holocene. Lastly, deposits within high-relief areas, such as hummocky hills, show little evidence of being affected by Holocene thaw. The ice within BH-2, located on a hilltop, displays depleted Pleistocene values ranging between $\delta^{18}\text{O}$ -30‰ to -27‰; at depths greater than 6-metres below the surface. Since the distribution and abundance of ground ice are strongly related to the geologic history of permafrost regions, future work will focus on placing these cores into a Quaternary geologic context and allow future trajectories of thermokarst to be identified.

The Mispickel gold deposit: A one-off system, or one of many?

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The Mispickel deposit, part of the Yellowknife City Gold Project, is contained within a wide deformation zone containing shears with abundant narrow (1-50cm) quartz veins that contain coarse-grained visible gold and low to moderate sulphides (arsenopyrite, pyrite, pyrrhotite) within subtle chloritic and sericitic alteration. The zone is hosted in turbiditic sediments of the Walsh Lake Formation. Units within the formation show abundant tight to isoclinal folding with probable N-S shear attenuation along fold planes.

On weathered outcrops, 2-7 m wide oxidized and highly fissile shear zones are evident. Quartz veins have biotite ('salt and pepper' veins) and can assay up to 300g/t Au over 1 m.

Although Mispickel only has a modest inferred resource of 64,000 oz Au, several indicators that are being teased out of various datasets suggest that Mispickel is larger than currently realized and that there are likely several other nearby zones like Mispickel, hence the new language of referring to Mispickel as a system.

Carbonatite-associated REE exploration in the Squalus Lake alkaline complex

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A preliminary field evaluation of rare earth elements (REE) mineralization in the Squalus Lake Alkaline Complex (SLAC) was undertaken for 9 days in the summer of 2021. The focus of the fieldwork was on identifying and characterizing sources of historical anomalous REE assays contained in assessment and government survey reports.

The Squalus Lake Alkaline Complex is a syenite-dominated concentric Proterozoic intrusion within the Archean Morose Granite. The intrusion is situated along the Phoenix Fault – a major NNE-trending crustal structure. The core of the complex coincides with a regional-scale magnetic high. These features suggest a classic concentric lithological zonation of the complex with a syenite rim and a carbonatite core. The magnetic anomaly is probably associated with a magnetite-rich ferro-carbonatite phase that typically occurs in the cores of most zoned alkaline/carbonatite complexes.

During the fieldwork, evidence for several carbonatite dykes were observed, both in outcrop and in angular float. The dykes are probably emanating from a carbonatite intrusion at the core of the complex, which is interpreted to be underneath Squalus Lake. Sites with reported anomalies were visited and re-sampled. An effort was also made at sampling the different lithological units that were observed.

Historically anomalous samples (obtained from the previous prospector) have been re-analyzed to confirm the results and attempts are being made at characterizing the potentials of the various host units. In classic alkaline/carbonatite complex models, high-grade REE mineralization is generally associated with the younger ferro-carbonatite phase at the core of the complex.

High grade REE mineralization tends to occur in late ferro-carbonatite phases. Previously collected ground-magnetic surveys provide strong discrete targets for the locations of the theorized ferro-carbonatite core, which is a primary target for REE endowment.

Curiously, the ~2180 Ma age of the SLAC is similar to the age of several other alkaline complexes in the Slave structural province, including the Big Spruce Lake Complex (~2188 Ma) and the Grace Lake Granite (~2176 Ma). The Grace Lake Granite is part of the Blatchford Lake Intrusive Suite, which is host to Canada's first REE mine at the Nechalacho Deposit at Thor Lake.

Nunavut overview 2021: New tools for exploration

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Exploration and deposit appraisal spending was higher in Nunavut in 2021 than in 2020, when the exploration and mining industry was hampered by the COVID-19 pandemic. Restrictions on travel into Nunavut have continued, but more operators were able to proceed with programs in 2021. Acknowledging the ongoing impacts of the pandemic, CIRNAC renewed the option for prospecting permit and mineral claim holders to request relief from their reporting requirements under the Nunavut Mining Regulations.

In January, Agnico Eagle Mines Ltd. acquired TMAC Resources and its Hope Bay mine, associated deposits, and regional prospects in the Kitikmeot, making Agnico Eagle the owner of all three active gold mines in the territory. Exploration in Nunavut was also gold-focused, with operators including Blue Star, Northquest, Fury Gold, Agnico Eagle, Western Atlas, and Sabina Gold & Silver conducting programs. Several Inuit prospectors were also active in the territory, mainly in the Kivalliq and western Qikiqtani.

North Arrow Minerals completed its bulk sampling program on the Q1-4 kimberlite at the Naujaat diamond project in September and acquired new claims in the western Kitikmeot. There has also been renewed interest in critical and battery metals in the territory, with Bathurst Metals planning a reconnaissance mapping and sampling program at two of its platinum-group metals properties in the western Kitikmeot, and Canadian North Resources completing a drill program at its Ferguson Lake nickel-copper-PGE project in the Kivalliq.

In December 2020 the Mineral Resources division released a new Nunavut Mineral Project Inventory, in preparation for the transition to the Nunavut Map Selection system, to highlight areas with economic potential for various commodities over which mineral tenure could be selected. The online Map Selection system was successfully launched on January 30, 2021, allowing prospectors and companies to acquire mineral tenure in Nunavut without having to put boots on the ground. The system has been well received, with many existing proponents using it to expand their mineral claim holdings, and new entrants to exploration in the territory accounting for at least 25% of the tenure acquired through Nunavut Map Selection.

Provenance of the Exeter Lake Esker and its application in mineral exploration

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Sampling and analysis of surficial sediment is an established method of resource exploration in glaciated terrain. For example, sampling of the Exeter Lake Esker led directly to the discovery of the Lac de Gras kimberlite field in the Northwest Territories and establishment of the diamond industry in Canada. During the initial sampling campaign, eskers were thought to act as regional “dipsticks” containing far travelled sediment extending the length of the esker system (100s of km). By contrast, till dispersal trains, from which esker dispersal trains are thought to be sourced, are typically perceived as being much shorter. To test this hypothesis, 56 paired esker and till samples with an average downflow spacing of 25 km were collected in Summer 2019 along the entire length (~750 km) of the Exeter Lake Esker. Following field work, the lithology of pebbles was determined visually, and the geochemistry of the mud (<63 µm) fraction was analyzed using a lithium-borate fusion followed by ICP-MS. Dispersal trains from the Dubawnt Basin, an SiO₂-rich siliciclastic unit at the up-flow end of the esker, are detected in the pebble and mud fractions in both the esker and till samples. Counter to the common perception, on a first order the dispersal trains in the esker mirror those in the till: there is no regional overshoot of esker dispersal trains beyond the till dispersal trains from which they were sourced in either the pebble or the mud fractions. For example, the concentration of Dubawnt pebbles in both the esker and till samples decreases rapidly from 100% to <50% ~25 km down-ice from the bedrock source and approaches 0% within 100 km from the bedrock source. Likewise, the concentration of SiO₂ in the mud fraction in both eskers and till decreases rapidly by 15% ~25 km down-ice from the bedrock source and levels out within 125 km from the bedrock source. If representative, the findings question the common perception that eskers contain regional dispersal trains of gravel, sand and mud that are significantly longer than those in the sub-adjacent till. Rather, both mediums may typically be composed of sediment of roughly similar provenance. This makes eskers excellent early exploration targets at the local scale, as they are capable of concentrating sand sized indicator minerals into easily traversable ridges which can be sampled much more efficiently when compared to traditional grid-like till transects.

The timing of deformation and kinematics of shear zones in the Nonacho Lake area

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The Nonacho Lake area is located along the western margin of the Rae craton in the southeastern Northwest Territories. This region is composed of the ca. 1.91-1.82 Ga siliciclastic Nonacho Group, previously interpreted to have been deposited in a fault-controlled basin, unconformably overlying Archean to Paleoproterozoic granitic and gneissic basement rocks. Detailed mapping during the 2019 and 2020 field seasons revealed two major sinistral, SW-striking, steeply-dipping, ductile to brittle shear zones, and several minor dextral, steeply-dipping shear zones. The major shear zones, King and Magrum shear zones, flank the western and eastern edges of the Nonacho basin respectively. Shear strain was accommodated in the Hjalmar, Chief Nataway, Tronka Chua and Thekulthili formations of the Nonacho Group and within underlying basement units. The minor dextral shear zones are located east of the Nonacho basin and deform Archean to Paleoproterozoic granite and gneiss.

A variety of geochronometers were applied to determine the timing of deformation of the shear zones in this region. Titanite grains elongated in the shear fabric of the King and Magrum shear zones were analyzed by U-Pb in situ LA-ICPMS and record dominantly ca. 2.3-2.2 Ga dates. Two CA-TIMS U-Pb zircon dates of 1.825 ± 0.0006 Ga were obtained from syn-tectonic granitic dykes in the Magrum shear zone and an ⁴⁰Ar/³⁹Ar date of ca. 1.78 Ga was obtained from sinistrally-deformed biotite in the King shear zone. In the minor dextral shear zones, U-Pb titanite dates range from 1.87-1.73 Ga. The obtained results indicate at least two periods of deformation within the two major shear zones flanking the Nonacho basin: 1) an early shearing event at ca. 2.3-2.2 Ga and 2) a sinistral, trans-tensional, greenschist-facies reactivation at

ca. 1.83-1.78 Ga. The earlier phase of shearing is coeval with the late stages of the Arrowsmith Orogeny and the later phase of reactivation is coeval with the extensional collapse of the Trans Hudson orogeny proposed for the South Rae craton during this time. The exact role of these shear zones in the exhumation of this region will be evaluated by a regional transect of $^{40}\text{Ar}/^{39}\text{Ar}$ data, that is currently being processed. Furthermore, given the two recorded periods of deformation, the King and Magrum shear zones were likely not a main control in the development of the Nonacho basin but rather deformed the basin following its development. This is corroborated by observed geologic relationships and recently published stratigraphic analyses and basin reevaluation.

Reconstruction of the depositional, structural and metamorphic history of the Arrowhead Outlier, Northwest Territories, Canada

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The Arrowhead Outlier, which is primarily composed of mafic volcanic rocks, is located in the west-central region of the Slave craton, ~300 kilometres northeast of Yellowknife in the Northwest Territories. The tectonic and metamorphic evolution of the Arrowhead Outlier is poorly understood; however, it is considered correlative to the well-studied Point Lake belt ~30 kilometres to the east. This project focuses on the geochemical, structural, and lithological study of the mafic volcanic rocks of the Arrowhead Outlier, aiming to correlate them with the Peltier Formation of the Point Lake belt.

The project objectives are to: 1) subdivide the volcanic rocks into volcanic facies; 2) document the geochemistry of the volcanic rocks in order to determine their petrogenesis; 3) determine the age relationship between the sedimentary, volcanic, and intrusive rocks; 4) assess the metamorphic grade; 5) collect structural measurements to reconstruct the deformational history; and 6) assess the style and economic potential of sulfide mineralization in the Arrowhead Outlier.

Three main hypotheses are formulated as a result of the field season. First, the volcanic rocks of the Arrowhead Outlier represent subaqueous eruptions and are a part of the Point Lake belt that have been separated by faulting and granite intrusions from the main belt. Second, the metamorphic grade of the metasedimentary rocks and the associated anatectic granites is sillimanite-zone amphibolite. Third, the main mineralization style within the Arrowhead Outlier is volcanogenic massive sulfide.

Detailed mapping at 1:2000 was completed from July to August. The mapping focused on the sedimentary rocks in the south-central fold hinge, across the thickest sequences of volcanic rock, and into the intrusive rocks that border the outlier. Preliminary results of this field work found that the volcanic core of the Arrowhead Outlier is composed dominantly of massive to pillow basalt with lesser amounts of bedded mafic tuff and gabbro. Mafic volcanic rocks are dominantly amphibolite-grade and locally mylonitized. Rare occurrences of mafic breccia, bedded heterolithic tuff, and bedded felsic tuff occur adjacent to mineralization. Mineralization hosted within the mafic rocks includes pyrite, arsenopyrite, pyrrhotite, chalcopyrite, bornite, and sphalerite. Metasedimentary rocks along the fold hinge consist of interbedded semipelites and psammites. To the west the semipelite is garnet-bearing and the psammite is cordierite-bearing, while to the east the semipelite contains knotted fibrolite and the psammite is barren of cordierite.

The intrusive and basement rocks are dominantly schlieren granite and syenogranite. Pegmatitic regions of the syenogranite contain schorl-variety tourmaline and garnet.

Next steps to understanding the history of the Arrowhead Outlier include petrographic analyses of major lithologies to more accurately identify their mineralogies. Analysis of whole rock geochemical data will further subdivide volcanic facies, determine the tectonic environment and source of the mafic lava, and aid to interpret relationships between the various lithologies. Analysis of assay data from visible occurrences of sulfide mineralization will aid to determine the mineralization styles present and assess the economic potential of the Arrowhead Outlier. Finally, utilizing both field mapping observations and geochemical data, two 1:2000 scale maps will be published.

Initial investigations of degrading dendritic peat plateaus in the central Mackenzie valley, Northwest Territories

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Peat plateaus dissected by dendritic fluvial and fen networks are common landforms in the central Mackenzie Valley, Northwest Territories. These networks tend to be associated with sloping site conditions (up to ~3 m per km), and are largely developed on moraine and glaciolacustrine sediments. These sites are often covered by tussocks, reindeer lichens (*Cladonia sp.*) and varying cover of open black spruce (*Picea mariana*). Field investigation of 3 sites in 2021 showed that peat thicknesses were ~2 m with structureless pore ice, that was overlaying several metres of ice-rich diamict or glaciolacustrine sediments. Electrical resistivity tomography profiles indicate that permafrost is typically thin in these areas (5-12 m), and through-going taliks forming the channel network are common, and increase in frequency downslope. The taliks appear to extend under the margins of the peat plateaus adjacent to the taliks, and are commonly captured to form the dendritic network. There seems to be little evidence for surface disturbances, and local depressions on the surface appear to extend into the underlying ice-rich sediments, and are very recent based on flooded black spruce (*Picea mariana*) and reindeer lichens (*Cladonia sp.*) within ponds. We hypothesize that these are slowly expanding thaw networks, likely driven by basal permafrost thaw near taliks.

Titanite as a U-Pb geochronometer for gold mineralization in the Yellowknife greenstone belt

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The Yellowknife Greenstone Belt is host to several world class orogenic gold deposits that have produced over 13 million ounces of gold since 1938. One of the main challenges in the geology of orogenic gold systems is relating mineralization to specific events (*e.g.*, intrusives or deformation stages) that can provide regional constraints on the structures most likely to be mineralized. The most direct way to relate mineralization to geologic events is through geochronology. However, mineralized veins consist of minerals that are very challenging to date (*i.e.*, quartz, sulfides, gold) or whose relationship to gold mineralization is unclear.

In the Yellowknife Greenstone Belt, the one geochemical factor that seems to correlate with gold independently of host lithology is an enrichment in titanium. This relationship has been proposed to occur due to titanium minerals contributing directly to gold precipitation. The replacement of ilmenite with titanite or rutile frees Fe²⁺ which reacts with bisulfide to precipitate pyrite/arsenopyrite. Destabilization of gold bisulfide complexes through sulfide precipitation then causes gold precipitation. In this process, the age of titanite would correspond to the age of mineralization, providing a geochronometer for gold mineralization.

In this study, we will be conducting U-Pb dating of titanite crystals from the Crestaurum, South Belt and Sam Otto drill sites using the formation of titanite as a proxy for gold mineralization. The first steps in this study will be assessing the abundance and size of titanite. Uranium and lead concentration will be measured in situ using LA-ICP-MS with a preliminary focus on Sam Otto, as previous analyses indicate that titanite in this claim is uranium-rich.

ESG & CSR performance of the Cheetah's Nechalacho rare earth mine during its first year of construction and operation

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Since the Geoscience Forum in 2020, Cheetah Resources Corp. has developed a northern workforce and northern supply chain, built, commissioned and operated Canada's first rare earth mine in the Northwest Territories, and with Marine Transportation Services, pioneered a new southbound marine and land route for mineral exports through Hay River.

A primary goal was to demonstrate that Cheetah could meet or exceed the average Environmental, Social and Corporate Governance (ESG) and Corporate Social Responsibility (CSR) performance measures for the Industry in the Northwest Territories, even though the capital cost and employment levels fell below the levels that would trigger Benefit Agreements.

Cheetah will report on its Key ESG/CSR Performance Indicators including, Indigenous and northern employment, procurement and training, health and safety, the environment, and COVID results.

The presentation will address the methodology, approaches and technology used to achieve these results, including novel approaches to the traditional mining business model, recruitment and retention, and new applications of proven technologies to metal mining that significantly reduced environmental impacts on the water, land, and air.

A TGI-6 task force to help de-risk exploration for IOCG, IOA, and affiliated primary critical metal deposits

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With estimated resources including 24 of the 31 critical metals on the Canadian list, iron oxide copper-gold (IOCG), iron oxide ± apatite (IOA) and affiliated primary critical metal deposits in metasomatic iron and alkali-calcic (MIAC) mineral systems are key to secure a long-term supply of critical metals for Canada. Canadian MIAC systems host undeveloped primary critical metal deposits such as the NICO Au-Co-Bi-Cu deposit in the Great Bear magmatic zone (Northwest Territories) and the Grenville Province Josette REE deposit (Québec). Other systems have significant infrastructures, 100s of km of drill cores and robust geoscience datasets such as the Camsell River district explored by the Dene First Nations in the Great Bear magmatic zone, the Scadding Au-(Co) deposit in the Southern Province (Ontario) and the Romanet Horst in the Trans-Hudson Orogen (Québec).

Research by the Targeted Geoscience Initiative and Geomapping for Energy and Minerals programs led to the development of an alteration (paragenetic) model that relates the alteration facies of MIAC systems to their mineralization and frames the genetic linkages between the systems' multiple styles of mineralization and metal associations. This model stems from extensive alteration mapping of Canadian MIAC systems and global comparisons. It explains the diversity of deposit types in Australia and other global MIAC mining districts that include skarn, IOA (±REE, ±Ni), iron-rich Au-Co-Bi-Cu (± Ni, Se, Te, W), IOCG (±Pd, Pt, REE, U), albitite-hosted U-Au-Co or Mo-Re deposits. The billion tons of resources in some global MIAC districts provide a strong reminder of the considerable resources potential of Canada's MIAC systems, including for critical metals. Yet vocabularies for mapping and logging MIAC systems are scanty and the collective ability to identify metasomatic (alteration) vectors to ore during regional mapping and exploration is fledging. Deposit models used for many Canadian MIAC-related prospects remain based on host rock types, structural controls or metal associations instead of on the metasomatic alteration facies that host mineralization. This situation undermines the identification of MIAC-affinities of

mineralization in certain geological provinces of Canada and precludes the assessment of the mineral and development potential of those geological provinces.

To mitigate and solve some of the exploration challenges posed by the complexities of MIAC systems, TGI and its national and international collaborators pioneer the use of alteration facies, geochemical discriminant alteration diagrams and molar barcodes at regional to deposit scale to establish the MIAC frameworks of prospective Canadian settings and global mining districts, including in high-grade metamorphic terranes. The team is also assembling a terminology for mapping and core logging systems, and extensive photograph libraries, series of short courses and an atlas to synthesize shared signatures of Canadian settings and global MIAC mining districts. The research will provide a foundation for the mapping and exploration of MIAC systems in non to highly metamorphosed terranes where surface and near-surface resources are still to be discovered and mined as are those of the Great Bear magmatic zone and beyond.

Update on recent and planned activities of the Office of the Regulator of Oil and Gas Operations (OROGO)

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OROGO holds regulatory responsibility for oil and gas operations in the onshore Northwest Territories outside of the Inuvialuit Settlement Region and federal areas. This presentation will provide a brief update on OROGO's activities over the past year and its plans for the coming year. Areas of focus will include the status of suspended wells in OROGO's jurisdiction, electronic well history and seismic program information, and compliance and enforcement activities.

The influence of water source on trace metals concentrations in the wetlands of the Slave River delta

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There are ongoing concerns within Communities along the Slave River about the cumulative environmental impacts from historical, current and planned upstream activities and climate change. Different pieces of the Slave River ecosystem have been studied over time to assess the health of this system. Nevertheless, the cumulative effects of various stressors on the status of nutrients and contaminants in Slave River Delta wetlands are unknown. One major concern is reduced seasonal flooding of delta wetlands by the main river. This will mean changes to the source of water for delta wetlands. The purpose of this study is to address knowledge gaps about the influence of water source on nutrient and contaminant levels in the interior wetlands of the delta. Across the broad expanse of the delta, some wetlands are mostly refilled with river water, while others are resupplied largely from snowmelt and rain. We are collecting water, sediment, algae, invertebrates and small-bodied fish to assess the influence of water source on levels of nutrients and trace elements in delta wetlands and trace metal movements in Slave River Delta food webs. This presentation will discuss project context, approach and preliminary trace metals data for at least six separate Slave River Delta sites. The results of this project will aid in predicting future trends of the delta and help to inform resource management decisions.

Northwest Territories mineral exploration and mining overview 2021

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Despite the ongoing COVID-19 pandemic, mining and exploration continued in the Northwest Territories. In 2021, NRCan's projects exploration spending of \$47.7 million, a 35% increase from \$35.4 million the previous year. So far in 2021, 66 claims have been staked and 116 cancelled, along with 8 leases issued and 4 leases cancelled. No prospecting permits have been issued to date.

Mining operations continued at Ekati, Diavik, and Gacho Kué mines. Vital Metals commenced production at the Nechalacho project, the first rare earths producer in Canada and the second in North America.

Gold Terra filed an updated NI 43-101 Technical Report on their Yellowknife City Gold project, with a 64% increase in the mineral resource estimate, as well as continued drilling on their Yellorex (Campbell Shear), Ranney Hill Shear and Crestaurum Shear targets. Nighthawk Gold Corp. completed a 272-drill-hole, 72,325 m drilling program on the Indin Lake Gold property. At Sixty North Gold's Mon project, drilling and sampling was carried out along the extension of a decline with plans to extract a 4,000 to 6,000 tonne bulk sample. Rover Metals completed a 31-drill-holes and ground geophysics at their Cabin Gold property, and announced a new drilling program at their Uptown Gold project.

Work continued on the Pine Point project, a past-producing Pb-Zn mine, with Osisko Metals Incorporated submitting an Environmental Assessment Initiation Package while also implementing a 3,000 m winter and a 13,000 m summer/fall drilling programs. NorZinc continued to advance the Prairie Creek project with additional drilling and permitting work, the release of a Preliminary Economic Assessment for a 2,400 tonne per day operation along with an MOU for the sale of concentrate. Fortune Minerals Limited continued work on their NICO Cobalt-Gold-Bismuth-Copper deposit with a 3,000 m drilling program.

Arctic Star Exploration Corp. discovered 5 new diamondiferous kimberlite pipes on their Diagras property. The Sequoia kimberlite yielded 499 stones from a 505.3 kg sample. Arctic Star also announced a 6,000 line-km airborne EM survey at 75 m line spacing. North Arrow Minerals Inc. drilled 6 holes on their Loki Project, which did not intersect the source of the prominent kimberlite indicator mineral train.

In the 2021-22 fiscal year, the Department of Industry, Tourism and Investment (ITI) awarded \$1 million through the Mining Incentive Program (MIP) to 15 successful applicants (7 corporate and 8 prospectors), primarily for early-stage mineral exploration projects. The Canadian Northern Economic Development Agency (CanNor) confirmed an additional \$500,000 in funding to support a second call for MIP applications in 2021-22, bringing the total program budget to \$1.5 million. The one-time winter MIP offering is focused on winter exploration and will provide five awards of \$100,000 each for mineral deposit targeting, mineral deposit testing, and innovative research and development projects that support advanced exploration and mineral production. From 2014 to 2018, the MIP directly leveraged \$11.8 million in company and prospector exploration spending. Historically, spending by companies and prospectors has been 3-4 times the MIP funds dispersed.

Tracking the source of fluids and fluid-rock interaction at the Cantung and Mactung tungsten skarn deposits, Northwest Territories/Yukon, Canada

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Cantung and Mactung are tungsten skarn deposits located in the Selwyn basin, Northwest Territories/Yukon. Cantung and Mactung are hosted in carbonate units surrounded by argillites and spatially associated with the mid-Cretaceous Tungsten suite granitoids. The Tungsten suite consists mainly of felsic intrusives, with local mafic (lamprophyre) dykes.

This study uses strontium isotopes to track the ore fluids source, the interaction of the ore fluids with the country rocks, and the broad magmatic sources in the study area. At Cantung, the most likely source of strontium in early scheelite (the tungsten-bearing mineral) are the Mine Stock monzogranite and related aplite dyke. In subsequent stages, the strontium isotopic composition more closely resembles the Cantung lamprophyre source magma, and/or local limestone units. In contrast, the isotope signature of all scheelite stages at Mactung closely resemble those of the Mactung granitoids, with slight incorporation of strontium from the country rocks.

The strontium isotope signatures of scheelite and local rocks are highly evolved, reflecting a crustal source. The strontium isotope signatures show different relative contributions of intrusives versus host rocks and therefore may serve as a tracer of the degree of fluid-rock interaction.

Broad scale aufeis mapping in the Northwest Territories

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Aufeis, commonly known as icings, are accumulations of layered ice that form during winter on the ground surface or on top of river or lake ice by the freezing of successive flows of groundwater or surface water. These features can be present in seasonal frost environments, but are most likely to occur in permafrost regions where frozen ground acts as an impermeable barrier to the movement of deep or shallow groundwater. Recurrent large aufeis features are of particular interest for groundwater investigations, as they are often related to groundwater discharge locations. Aufeis distribution can also inform studies of permafrost distribution and associations with landscape geomorphology.

Several initiatives in the past decade have mapped aufeis features at regional scales using satellite imagery. The objective of the current project is to refine the methodology previously developed to identify large recurrent aufeis at a broad spatial scale in Northwest Territories using Landsat imagery. The outputs of the project will be of interest from a groundwater perspective as they have the potential to indicate spatial patterns of groundwater resurgence, identify relevant groundwater monitoring locations, and provide a useful tool to follow the evolution of permafrost and groundwater dynamics in the context of climate change. Project outcomes are also anticipated to support current broad scale mapping of permafrost landforms, thermokarst features, and related geohazards in the Northwest Territories.

Development of regulations under the Mineral Resources Act

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The Government of Northwest Territories, led by the Department of Industry, Tourism and Investment (ITI) achieved a new Mineral Resources Act under the mandate of the 18th Legislative Assembly, through a collaborative development process with the Intergovernmental Council and Indigenous governments and organizations. The Act received assent in 2019. In order to come into force, comprehensive regulations must be developed.

The regulations will provide details on several significant and complementary frameworks that will modernize the tenure process in order to create benefits for Indigenous peoples and Northwest Territories residents, review the royalties system, and build relationships. This presentation will focus on the regulations development process but also touch on implementation.

An evaluation of magmatic processes responsible for tungsten enrichment in the Canadian tungsten belt: Evidence in melt inclusions of granitoids associated with the Cantung and Mactung W-Cu deposits

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The world-class Cantung and Mactung W-Cu-Au skarn deposits are hosted in limestone of the Selwyn Basin, where it is intruded by a series of Cretaceous-aged granitoids known as the Tungsten plutonic suite. Tungsten and the associated metals (*e.g.*, Au, Cu, Mo, Sn) in W skarn settings are thought to be provided and transported by exsolved magmatic-hydrothermal fluids from the granitoids. Several mechanisms for W enrichment in fertile magmas have been proposed, all of which focus on the incompatible element (IE) behavior of W during protracted fractional crystallization due to i) mid-crustal depths of magma staging and emplacement, and/or ii) high dissolved volatile content, and/or iii) reduced oxidation conditions that prevented fractionation of W in phases such as magnetite.

This study aims to determine the major and trace element concentrations of apatite-hosted silicate melt inclusions (SMI) from the Mine Stock and associated aplite dykes at the Cantung deposit, as well as the Cirque Lake and Rockslide Mountain Stocks and leucocratic dykes at the Mactung deposit. The major element composition of homogenized SMI will be gathered *via* electron probe microanalysis (EPMA) to classify the tectonic environment of the magmas. The trace element abundances of homogenized and non-homogenized SMI will be acquired *via* laser-ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) to determine the W and other important ore elements (*e.g.*, Au, Mo, Sn) concentrations of the melts during different stages of fractional crystallization. The data will also be used to model the behavior of the trace elements during fractional crystallization by using the petrography results and mineral-melt partition coefficients of the minerals in the rock samples in batch crystallization calculations.

Preliminary data of the SMI show a wide range in compositions from intermediate to felsic reflecting the trapping of melts at different stages of fractional crystallization. The transition from syn- to post-collisional may also reflect the entrapment at different stages. Tungsten content in the most evolved melts is up to three orders in magnitude higher than the average crustal values as well as the whole rock data. The inclusions with the lower IE represent melts trapped during the earliest stages of fractional crystallization. Positive correlations between Zr/Hf and Nb/Ta indicate the preferred fractionation of Nb and Zr in biotite and zircon, respectively. The negative correlation between Nb/Ta and Ta indicate the incompatible behavior of Ta during biotite crystallization. When compared to the concentrations of Ta and other IE, W shows enrichment during fractional crystallization reflecting its incompatible behavior with crystallizing phases.

This research will give insights into the source of W and magma at the Cantung and Mactung deposits and supplement the scarcity of melt inclusion data on W-skarn deposits. The controls of W enrichment (magma emplacement depth and/or volatile content and or/ fractional crystallization) in magmas associated with W skarn deposits will be evaluated by comparing the data with other melt inclusion studies from other intrusion related W deposits, porphyry deposits, and barren environments.

The origin of barite and formation of 'superheavy pyrite' in the Late Devonian Canol Formation, Selwyn basin, Canada: Insight from pyrite ($\delta^{34}\text{S}$) and barite ($\delta^{34}\text{S}$; $\delta^{18}\text{O}$) in-situ stable isotope analyses

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Barite (BaSO_4) is a critical raw material widely used in the drilling mud and a key component in radiative cooling applications. Some of the largest barite deposits in the geological record are spatially associated with large clastic dominant (CD-type) Zn-Pb massive sulfide deposits. In the Selwyn Basin (Canada), bedded barite deposits are hosted by black mudstones of the Late Devonian Canol Formation, where barite comprises disseminated, laminated, and nodular styles that are common in an assemblage with pyrite. The origin of the pyrite and barite, and whether it formed *via* diagenetic or hydrothermal processes, has been the subject of extensive debate. This study describes barite and pyrite in samples collected from multiple sections of Late Devonian stratigraphy (Northwest Territories), which are broadly correlative with the unit that hosts CD-type deposits at Macmillan Pass (Yukon). Detailed high-resolution scanning electron microscopy (SEM) has been coupled with in-situ secondary ion mass spectrometry (SIMS) isotopic analyses ($n=1032$) of pyrite ($\delta^{34}\text{S}$) and barite ($\delta^{34}\text{S}$ and $\delta^{18}\text{O}$). The $\delta^{34}\text{S}$ barite (+37.1‰ to +67.9‰) and $\delta^{18}\text{O}$ barite (+8.8‰ and +23.9‰) values represent a substantial offset from Late Devonian seawater sulfate, consistent with precipitation from modified diagenetic pore fluids. The coexistence of the barite with 'superheavy' pyrite ($\delta^{34}\text{S}$ Pyrite > $\delta^{34}\text{S}$ SO_4 (Seawater)) also demonstrates coprecipitation under progressively sulfate-limited conditions. The replacement of diagenetic barite by Ba-bearing phases (*e.g.*, witherite, cymrite, and hyalophane) provides further evidence of severe sulfate depletion and conditions under which barite was soluble. The diagenetic assemblage formed at the sulfate methane transition zone (SMTZ) where opposing diffusional fluxes of methane (+barium) and sulfate mixed and resulted in sulfate reduction coupled to anaerobic methane oxidation (SR-AOM). The regional extent of this authigenic mineral assemblage in the Selwyn Basin indicates the important role of SR-AOM in the Late Devonian sulfur cycle.

Re-interpretation of the geology suggests the Campbell Shear extends north of the Giant Mine along the west shore of Walsh Lake

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Reconstruction of the gold-bearing structure from the Giant Mine deposit along the West Bay Fault by Neil Campbell in the 1940s led to the discovery of the Campbell Shear at Con Mine, from which approximately 5 Moz of gold was produced. The Campbell Shear occurs between two unconformities, namely the Bode Tuff, a debris flow, and the Jackson Lake Formation, a conglomeratic unit. North of the Giant Mine only the Jackson Lake Formation was recognized and mapped. The unconformity marked by the Bode Tuff was assumed to pinch out around the Vee Lake area. However, recent mapping done north of the Giant Mine along the west shore of Walsh Lake has revealed a debris flow that is similar to the Bode Tuff. A major shear (up to 100 m-wide) was also mapped between this unconformable debris flow and the Jackson Lake Formation to the east. Although several historical trenches were dug over decades of exploration, the structure was never recognized as being the potential north extension of the Campbell Shear. Surface samples show anomalies in arsenic and antimony with only traces of gold (below 100 ppb level). This new interpretation is ground-breaking since it opens the possibility of finding another gold deposit hosted in a Campbell Shear-like structure north of the Giant Mine.

Ocean, marine life, and anoxic events during warm ice-free epochs: What Devonian rocks of the Northwest Territories can tell us

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The ongoing global warming, poleward migration of species, and retreat of ice is undeniable. These changes, easily observable on land surface, are coupled with ocean response to global warming - slowdown in thermohaline circulation and linked processes that will be highlighted in this presentation. The ultimate global warming called the greenhouse Earth-surface condition, when polar ice caps melt completely and ocean is predicted to undergo a profound change from bottom to top, is unexperienced by people as a biological species. Being the smartest terrestrial life form, we have technological capacity to prevent such future. However, for our learning about this ice-free potential future, sedimentary rocks provide indispensable information about protracted greenhouse states of Earth's surface lasted for tens millions of years during deep geologic past. One such sedimentary archive is the strata of the Horn River Group in the Northwest Territories. Excellent outcrops of these basinal shales, cherts, and carbonates occur on

cordilleran ranges in Sahtu Lands on both sides of central Mackenzie Valley. Representing the geologic age range of ~373-386 Myr (Givetian and Frasnian stages of Devonian System in Geologic Time Scale), these strata provide a rare-to-find, well-preserved archive of paleo-oceanographic signals imprinted in oxic and anoxic facies deposited in close proximity to each other. Four global anoxic events are recognized in these strata by using elemental and organic geochemistry, gamma spectrometry, and stable carbon isotope data. Age constraints are biostratigraphic, mostly provided by conodonts. The discovery of aryl isoprenoids (organic molecular compounds specific for green sulfur bacteria) at and between the levels of anoxic events contributes to the growing evidence of shallow, sunlit chemocline (the boundary separating oxygenated and oxygen-free waters) as a normal condition of then-time shelfal seas. This condition is not possible under present-day vigorous ocean circulation unless the sea is landlocked and semi-isolated from ocean circulation cells. Presented data collectively support a school of thought that discards sea-level changes as a control over these ancient oceanic anoxic events. Rather, the data suggests these events were pulsatory expansions of thick and laterally extensive oxygen minimum zones. This non-actualistic state of ocean was conducive for accumulation of enormous hydrocarbon reserves of the Western Canada Sedimentary Basin, including its northern continuation in Northwest Territories. On the other hand, there are indications that Devonian pulses of anoxia could promote precipitation of metalliferous (Ni-Mo-Zn-Pt-Pd-Au-Re...) horizons under conditions of extreme and protracted sediment starvation. Such horizons are known in the Middle Devonian of northeast Yukon. This work is a contribution to the Geomapping for Energy and Minerals Program.

Unravelling the effects of deformation on clastic-dominated Zn-Pb deposits: A case study of the Howard's Pass XY deposits

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Clastic-dominated (CD) sulfide deposits are a major source of critical metals (Zn, In, Ge, *etc.*) that are needed for the global transition to a green energy economy. These deposits typically form in extensional basins located near the edge of intact continental lithosphere and are prone to crustal shortening in later orogenic events. As a consequence, CD deposits commonly undergo ductile deformation and metamorphism as the host basins are incorporated into developing fold-and-thrust mountain belts. Basin structures may reactivate and concentrate deformation into different structural domains. Such deformation can have significant effects on the spatial distribution of ore and its associated sulfide mineralogy and gangue.

The CD Zn-Pb deposits of the Howard's Pass district represent one of the world's largest undeveloped massive sulfide districts. Sulfide deposition occurred during the Silurian and the deposits were deformed during the Cretaceous Cordilleran Orogeny. The Zn-Pb deposits have been incorporated into a series of upright to steeply inclined WNW striking, gently plunging folds in a 40 km corridor along the border of the Yukon and the Northwest Territories. Owing to the structural complexity of deposits, multiple models have been proposed for their evolution. A recent model proposes that the deposits are hosted in a regional shear zone where transposition of bedding and thrust faulting has resulted in previously interpreted stratigraphic boundaries being tectonic in origin.

This study aims to test this hypothesis and is focused on the XY group of deposits of the Howard's Pass district. Lithostratigraphic and structural mapping indicate one main phase of folding, F_1 , is responsible for the gross geometry of the deposits. The XY cluster is located on the southern limb of a macroscopic syncline. A regionally developed, steeply NE dipping, cleavage, S_1 , is axial planar to F_1 folds. The S_1 fabric manifests as a slaty cleavage comprising pervasive dissolution seams. The mineralization at XY is hosted in the Duo Lake Formation. In mineralized strata, S_1 forms sulfide-rich dissolution seams with local remobilization of sphalerite, galena, and pyrite. The seams are axial planar to microfolds and transition to a stylolitic dissolution foliation in intervening layers of non-mineralized carbonaceous mudstone. A later kink fabric, S_2 , crenulates S_0 and S_1 at the microscopic and mesoscopic scale and shows a sinistral sense of asymmetry. A series of WNW and NNE striking faults exhibit normal dip-slip movement and overprint F_1 folds. Lithofacies adjacent to these faults preserve no evidence that they were active at the time of sedimentation or controlled the upwelling of metalliferous fluids that formed the XY deposits.

Results from this study indicate that the geometry of the XY deposits is primarily controlled by folding and contacts between units are dominantly stratigraphic in origin. S₁ and S₂ are the only foliations observed. No shear zone fabrics were identified and there is no evidence for strong transposition of bedding. Ongoing work will integrate modern geochemical and microanalytical techniques to evaluate the scales at which sulfides are remobilized and assess the impacts of remobilization on the economic viability of orebodies in deformed CD deposits.

Bedrock mapping in the “Arrowhead” outlier of the Point Lake greenstone belt

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In 2021 the Northwest Territories Geological Survey (NTGS) continued bedrock mapping project approximately 330 km northeast of Yellowknife, within the Point Lake greenstone belt “Arrowhead” outlier and the surrounding granitoid complex. This mapping was conducted at 1:20,000 scale in conjunction with targeted 1:2000 scale mapping by collaborators at the University of Saskatchewan. This work aims at improving the knowledge of ore-forming processes and to better understand controls on base and precious metal endowment. Through mapping, details about the nature of emplacement and the thermotectonic history of volcanic and sedimentary rocks, and associated volcanogenic massive sulfide (VMS) style mineralization, is being revealed. This mapping is utilizing a 65,000 line-km high-resolution magnetic survey to provide 3D insights into the outlier geometry. Magnetic susceptibility data were collected in the field to support the creation of more robust 3D geophysical inversions.

Within the “Arrowhead” outlier volcanic and sedimentary rocks have recorded multiple thermotectonic events and are bounded along their margin with granitoids by steeply dipping faults. Massive mafic rocks (volcanic and associated intrusive) and pillow basalts dominate the volcanic stratigraphy. Minor mafic breccias, mafic and intermediate tuffs, and rare local felsic tuffs were also observed. The metasedimentary rocks range in composition from psammites to pelites. The thin to medium bedded sedimentary rocks contain corderite and andalusite +/- sillimanite +/- partial melt in the northwest corner of the outlier. The metamorphic grade increases towards the south and west where the rocks are gneissic migmatites and contain sillimanite and anatectic melt. Towards the margin of the “Arrowhead” outlier the percentage of anatectic melt and intrusion pre- to syn-kinematic granitoids increases. The percentage of intrusive material increases outward from the greenstone belt until xenoliths and schlieren make up 5% or less of the rock. Also, along the greenstone belt margin interlayering of volcanic and sedimentary rocks was observed, indicating synchronous deposition for at least part of its history.

Although the “Arrowhead” outlier has a lack of previously known mineralization, our work aims at testing correlating these volcanic rocks with those in the Point Lake greenstone belt that host the IZOK Lake VMS deposit. Through our work a significant number of volcanic rock-hosted VMS style mineralization was observed in the course of our work. Variable grades of VMS-style mineralization ranged in size from a few inches to metres to 400 by 800 metres. Quartz vein-hosted mineralization was also observed cross-cutting volcanic and metasedimentary rocks.

Permafrost science capacity in the Northwest Territories

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Permafrost affects ground conditions across the Northwest Territories and is the foundation for northern ecosystems, communities and infrastructure. Climate change is altering permafrost with major implications to the environmental, economic, and social well-being of the Northwest Territories. The Government of Northwest Territories (GNWT), academic and Indigenous Organizations, as well as industry recognize that permafrost knowledge and a significant increase in northern permafrost science capacity is critical to support a resilient territory in a rapidly changing north. It is

in this context that GNWT established a Permafrost Science Team at the Northwest Territories Geological Survey (NTGS) in 2020-21 and concurrently developed a strategic plan. The plan communicates the vision, mandate and strategies that will be implemented by an Northwest Territories Permafrost Science Team with support from its key partners. With input from government, academic, Indigenous, and industry partners, the team established the following four goals: A) Conduct and support research and monitoring that generates Northwest Territories relevant permafrost knowledge; B) Provide scientific leadership, mentorship and advice to advance the state of permafrost knowledge, and to support decision-making in the Northwest Territories; C) Lead the stewardship of Northwest Territories permafrost data; and D) Foster a community of permafrost experts who bring positive energy and diverse talents to their work and advance professional and public awareness of permafrost science and its relevance in the Northwest Territories. In this presentation we elaborate on the Permafrost Team's Strategic Plan, provide a brief overview of new permafrost science staff, identify key partnerships, and briefly summarize the main permafrost research themes that will guide NTGS science and monitoring activities.

Study of metal mobility from mine tailings – Any risk to the environment?

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Mining activities produce waste rock and tailings that represent a potential risk of toxic metal release into the surrounding environment. Tailings consist of fine particles with large surface area and high adsorption capacity. The presence of sulfide minerals can cause acid rock drainage issues. Fine particles of tailings are easily transported by wind, precipitation, and runoff water and deposited on land and water bodies.

Two tailings from gold and silver mines in Canada were selected and extracted using a rain mimicking procedure (synthetic precipitation leaching procedure by EPA 1312), and a sequential extraction process known as the “three-step BCR sequential extraction” that uses acid, reducing and oxidizing conditions (European Commission Community Bureau of Reference). The major metals (Al, Ca, Fe, Mg, and Mn) in tailings and 16 toxic metals (including As, Be, Cd, Co, Cr, Cu, Li, Mo, Ni, Pb, Sb, Se, Tl, U, V, and Zn) regulated for water quality by Environment and Climate Change Canada were analyzed using Inductively Coupled Plasma Mass Spectrometry. This study aimed to understand the mobility and geochemistry of these metals when exposed to leaching conditions simulating environmental exposure.

The tailings were kept at site in a neutral to slightly alkaline pH. A single extraction using precipitation extraction resulted in virtually no trace metal release. However high concentrations of Ca and Mg were observed. While the three-step sequential extraction mobilized a larger proportion of trace metals from the tailings, acid extraction step 1 dissolved a large portion of Ca and Mg along with Cd, Cu, Mn, and Zn. Meanwhile Fe as a major constituent of clay particles was highly released in reducing conditions in step 2 together with Ca, Ni, and Pb. During step 3, under oxidizing conditions, Fe (possibly from sulfide minerals) was observed in a high concentration as well as Cu, Ni, Se, U, and Zn. It was observed that most of Al, Be, Cr, Li, Mo, Sb, Tl, and V remained immobile in the residue phase of both tailings.

The sequential extraction could be used as a tool to predict the potential release of toxic metals from mine wastes. The concentration of metal released from tailings depends on types of tailings and the storage conditions. Higher concentrations of toxic metals were observed in silver tailings. Both tailings released high levels of Ca and Mg, which may result from storage conditions.

Chemical characterization and timing of uranium mineralization in the Nonacho Basin, Northwest Territories

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The intracratonic Paleoproterozoic Nonacho Basin, deposited on the western margin of the Rae craton, contains polymetallic (*i.e.*, U, Cu, Fe, Pb, Zn, Ag) occurrences near the unconformable contact with crystalline basement rocks. Exploration began in the 1950s following detection of anomalous radioactivity, leading to preliminary investigations of numerous U occurrences.

Two distinct styles of U mineralization are associated with the Nonacho Basin: primary uraninite of the Hope occurrence (northern basin) is disseminated within hydrothermally altered quartz-biotite-albite rich deformation zones within the basement gneisses, whereas later chlorite-calcite \pm quartz vein-hosted and disseminated secondary U-hydroxides occur in basement granitoids and basinal siliciclastics near MacInnis Lake (south-central basin). Although separated by over 50 km, the two areas are connected by a series of north-east trending fault structures.

At the Hope showing, milled albitized-oligoclase clasts are hosted in a hydrothermal quartz-biotite corridor. Coarse grained Th-rich uraninite occurs as overgrowths on and as intergrowths with metamict zircon and is characterized by four distinct U-Pb ages: (i) primary magmatic uraninite crystallization at 2784 ± 21.7 Ma, ii) isotopic resetting by magmatic heating at 2614 ± 10.5 Ma, iii) isotopic reworking at 2531 ± 17.4 Ma by the MacQuoid Orogen, and (iv) alteration by hydrothermal fluids at 1778 ± 14.4 Ma, which also precipitated biotite (1834 ± 1.2 Ma; Ar-Ar) and molybdenite (1794 ± 28 Ma; Re-Os). Molybdenite and chlorite locally overprint biotite, and are coeval with the hydrothermal resetting of uraninite. Local pseudomorphs of biotite by muscovite with thorite may indicate dissolution of early uraninite by low-T, acidic fluids.

MacInnis Lake showings contain fine-grained, Pb-poor, heterogeneous U-hydroxides (*i.e.*, uranophane and coffinite). This mineralization is associated with chlorite-calcite \pm quartz veins which post-date albitization and potassic alteration of host rocks. Two modes of occurrence have been recognized: (i) as overgrowths on earlier, partially dissolved bornite and chalcopyrite; and (ii) associated with hematite and rutile and pervasive sericitization of chlorite. Rare-earth element concentrations of U are high, up to 9.5 wt.% and have high HREE/LREE values which resemble REE signatures of intrusive U and IOCG-IOA style mineralization. Extensive albitization and localized potassic-iron alteration associated with remobilized vein-hosted U resembles albitite-hosted U (+hematite+chlorite+K-feldspar) of the Southern Breccia IOCG system in the Great-Bear Magmatic Zone. MacInnis Lake U may ultimately be derived from early U occurrences such as Hope, which were remobilized by fluids along regional-scale faults and precipitated on Fe-bearing sulfides and silicates, which acted as a redox trap for mineralization, in relatively high temperature ($313\text{-}333^\circ\text{C}$) chlorite-calcite \pm quartz veins.

Banded iron formation–hosted gold deposits in Nunavut and a new prospect

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Nunavut has reached a milestone for the first time ever by surpassing the Northwest Territories' value of mineral production in 2019-2020. This is largely due to an increase of banded iron formation- (BIF) hosted gold production, mainly by the opening of Agnico Eagle Mines Limited's Meliadine and Amaruq mines in 2019. Moreover, BIF-hosted gold is projected to become increasingly important for Nunavut with the opening of Sabina Gold and Silver's Back River soon-to-be mine. To quantify the importance of BIF-hosted gold in Nunavut today, approximately 528,302 ounces of BIF hosted-gold (from Meliadine and Meadowbank complex) were produced in 2020, valued at ~\$1.06 billion (at \$2,015/oz). Natural Resources Canada estimates this as a 27% increase over 2019, which builds on an increase of 57% from 2018.

Although there are many types of gold deposits, the BIF-hosted gold deposit is arguably one of the most highly sought-after because of its potential for high-grade, high-tonnage, and long lasting mine life. All three regions of Nunavut (*i.e.*, Kivalliq, Kitikmeot and Qikiqtaaluk) contain BIF-hosted gold deposits, some of which are considered world class. Two of Nunavut's mines and four exploration properties and their geology will be briefly reviewed. The mines include Agnico Eagle's Meadowbank complex (Portage, Goose and Amaruq deposits) and the Meliadine mine district of the Kivalliq region. Exploration projects include: Fury Gold Mines Limited's Three Bluffs project, Mandalay Resources Corporation's Lupin former mine, and Sabina Gold and Silver Corporation's Back River project (all of the Kitikmeot region), and ValOre Metals Corporation's Baffin Gold project (Qikiqtaaluk region).

Upon review of the nature of each of these BIF-hosted gold deposits, recurring characteristics emerge that can be useful for future exploration in Nunavut and worldwide. These characteristics include a thick BIF unit (oxide and silicate facies, decametres in thickness); strong deformation and dominant structural controls on ore (faults and folds); greenschist- to amphibolite-facies metamorphism; and a sulphide-mineral assemblage dominated by pyrrhotite, with possible arsenopyrite±loellingite and lesser chalcopyrite and pyrite along quartz-carbonate veins and/or as stratabound replacements.

During the 2019 fieldwork for the Fury and Hecla Geoscience Project led by the Canada-Nunavut Geoscience Office, a previously unknown, deformed BIF unit of significant thickness and lateral extent was discovered on northwest Baffin Island. Here, preliminary field observations, petrography and geochemistry of this BIF unit are presented. Although this work is preliminary, further exploration of this BIF is warranted.

Sedimentology of the Paleoproterozoic Nonacho Basin, Northwest Territories, Canada: Results from the 2021 field season

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Reconstructing the depositional record of sedimentary basins is pivotal to understanding tectonic processes that influence their formation and evolution. The Paleoproterozoic Nonacho Basin in the southeastern Northwest Territories has a basin fill consisting of, from oldest to youngest, the Hjalmar, Tronka Chua, Chief Nataway, Newshethdezza, Thekulthili and Taltson formations. These units record clastic deposition in alluvial, fluvial, and marine environments during the accretion of the ancestral Canadian Shield. Presented here are the results of the summer 2021 fieldwork aimed at refining the extant stratigraphic framework of the basin. New determinations about facies variants, depositional environments, and their associated spatial lithostratigraphic relationships were elucidated by mapping traverses, stratigraphic logging (bed-by-bed logs and the first-ever stratigraphic section across a formation boundary), and detailed facies analysis. A previously inferred unconformity in the upper Nonacho Group between the Newshethdezza and Thekulthili formations is disproven in the central basin area. Furthermore, gradational contacts also occur between the Tronka Chua, Chief Nataway and Newshethdezza formations in the same area. The depositional environments of the Chief Nataway, and the overlying Newshethdezza, formations were determined to be an offshore transition zone and a channelized system, respectively. Key sedimentary structures combined with grain-size trends demonstrate a stratigraphic-upward change from proximal to distal detritus source areas followed by a return to a proximal source. Our new understanding of the stratigraphic succession, together with recent U-Pb detrital zircon data, corroborates the hypothesis that the Nonacho Basin formed due to tectonic relaxation punctuated by a period of crustal flexure. More broadly, the new field data expand the understanding of clastic sedimentation of the Rae craton's supracrustal assemblages.

Evaluation of the metasedimentary rocks within the Archean Winter Lake greenstone belt, Slave craton, Northwest Territories, Canada

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The Archean Winter Lake greenstone belt (WLB) in the Slave craton, located ~250 km north-northeast of Yellowknife, is one of several greenstone belts preserved along the proposed eastern edge of the Central Slave Basement Complex and has an enigmatic relationship with the Beniah fault zone. The WLB contains poly-deformed metavolcanic and metasedimentary rocks that span ca. 3.3 Ga to 2.6 Ga. This project aims to understand the depositional and tectonic settings of the metasedimentary units referred to as the Itchen Formation (turbidite-like) and the Sherpa Formation

(Timiskaming-like) and assess their compatibility for structurally-hosted lode gold mineralization, ultimately attempting to understand how these rocks fit into the overall geological architecture and evolution of the Slave craton as a whole.

Fieldwork completed during the summer of 2021 around the Shallow Lake/Left Lake area consisted of 1:2000 scale mapping to compile information regarding facies, stratigraphy, and contact relationships, as well as the collection of a variety of samples for future analysis. Preliminary findings based on the 2021 field season indicate: 1) the depositional environment for the Sherpa Formation is consistent with alluvial/fluvial high-energy environments, and the Itchen Formation is consistent with marine low-energy environments; 2) the dominant sediment source for the Sherpa Formation consists mainly of granitic material with subordinate mafic clasts (volcanic and intrusive), mudstone clasts, sandstone clasts, and ultramafic clasts – likely generated along local fault scarps, whereas the provenance of the Itchen Formation requires further isotopic analysis and thin section work to be understood, given its fine-grained nature; and 3) contact relationships, metamorphic mineral assemblages, and deformation recorded in both sedimentary units suggest a short-lived hiatus between the two formations; however, a possible paleosol preserved between the Sherpa Formation and underlying basalt, paired with the environments of depositions, metamorphic grade, and structural history, suggests a major unconformity.

Future work includes: 1) detrital zircon U-Pb geochronology and Lu-Hf isotope data for provenance analysis and evolutionary fingerprinting; 2) whole-rock major and trace element geochemistry to investigate the evolution of fine-grained siliciclastic rocks, as well as to evaluate the degree of chemical alteration; 3) microprobe analysis on Grt-Bt (geothermometer system) and Grt-Al₂SO₅-Qtz-Plg (geobarometer system) to assess the P-T-t path, specifically in the Itchen Formation as it contains a robust metamorphic mineral assemblage that varies across the preserved sedimentary basin; 4) assay analysis of mineralized samples within quartz veins and shear zones to assess gold potential; 5) refining detailed maps and stratigraphic sections through the Sherpa and Itchen formations; and 6) detailed petrology to determine compositions, metamorphic mineral assemblages, provenance, and ore potential.

The results of this study will provide a robust sedimentological and thermotectonic understanding of the WLB and aid our comprehension of other supracrustal sedimentary sequences and the overall evolution of the Slave craton.

Protecting Ts'udé Niljné Tuyeta: What can wetlands tell us about ongoing environmental change?

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The diverse and abundant wetlands of the Ts'udé Niljné Tuyeta Indigenous Protected Area, west of Fort Good Hope, in the Sahtú Settlement Area, are highly valued natural resources, with unique cultural and ecological importance. In addition to providing ecosystem services such as filtering and storage of surface water, these wetlands also provide key wildlife habitat that supports subsistence hunting. Yet, since the 1950s, annual average air temperatures have increased twice as fast in northern North America as elsewhere in the world, and estimates of wildfire activity suggest that increases in the extent and frequency of forest fires will be greatest in northwestern Canada. Accompanying such landscape-level changes are changes at the ecosystem level, including increases in water temperature, as well as changes in biological productivity and contaminant cycling. Although the combined effects of such changes on the wetlands and the wetland-dependent wildlife of Ts'udé Niljné Tuyeta are difficult to predict, knowledge from local Indigenous people (*i.e.*, Traditional Knowledge) suggests that change on the land is already having a profound influence on water quality and on biota.

To co-develop and establish a water quality monitoring and research program in Fort Good Hope, Indigenous leaders in this community partnered with scientists at Environment and Climate Change Canada, with a general goal of evaluating the impacts of environmental change (related to forest fires) on water quality and wetland ecosystems in Ts'udé Niljné Tuyeta. Since 2017, this monitoring and research program has provided training and employment

opportunities for Indigenous Guardians and has also developed and implemented sampling protocols for long term, community-based monitoring of freshwater ecosystems. Ongoing work with partners in Fort Good Hope and Environment and Climate Change Canada continues to focus on enhanced training for Indigenous Guardians and on monitoring water quality as it relates to changes on the land.

Chemostratigraphic and biostratigraphic analysis of the Duo Lake Formation at Howards Pass in the Selwyn Basin region, Northwest Territories

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Howards Pass is a major, 38 km-long district of shale-hosted zinc-lead deposits in western Northwest Territories and eastern Yukon. Fifteen separate deposits are hosted by carbonaceous lime mudstone and mudstone of the Ordovician-Silurian Duo Lake Formation. The existing stratigraphic framework for that unit was based on lithostratigraphic correlation of multiple poorly exposed, partial sections of outcrop and drill core; and the structural model of a simple syncline has been challenged by the suggestion that the district lies within a thrust duplex. Successful prediction of ore distribution will rely on a valid structural model and a robust framework for the internal stratigraphy of the host unit.

This study aims to test the usefulness of high-resolution carbon-isotope stratigraphy in detecting imbricate thrusts within the Duo Lake Formation. In 2016, an outcrop section and drill core from two separate deposits were logged and sampled.

There is a zone of high strain at the base of Duo Lake Formation in all three sections and numerous smaller faults throughout the formation. Detailed lithological study found insufficient evidence to recognize previously described members in the studied sections. Although compositional units could be identified, none of the units was present in all three sections, which could reflect facies changes, modification by secondary processes, or fault disruption of the stratigraphy.

Identifiable graptolites were found at several levels within the outcrop section, including faunas of Darriwilian (Middle Ordovician) age near the sheared basal contact with Rabbitkettle Formation, Rhuddanian (earliest Silurian) graptolites at the top of the section, and some Katian (Late Ordovician) collections in between. Unfortunately, it is not possible to reliably correlate these strata into the core sections.

A total of 392 samples from the three sections were analyzed for the carbon isotope composition of their organic matter. In all three sections there are intervals with $\delta^{13}\text{C}_{\text{org}}$ values of ~ -27.0 to -28.5 ‰ near the base. In the core sections these values gradually decline to ~ -30 to -31 ‰ near the middle, then gradually return to higher values near the top. Superimposed on these overall patterns are shorter stratigraphic intervals of weak positive excursions. Higher in the sections, both cores show a positive shift in values coinciding with the highly mineralized unit, overlain by a stronger positive shift at or near the top. These similarities suggest that the two core sections span a similar stratigraphic interval, supported by similarities in the lithologies and patterns of variation in their total organic carbon content. None of the studied sections show any evidence of stratigraphically repeated patterns of $\delta^{13}\text{C}_{\text{org}}$ values that would be expected if there were stacked sets of strata repeated by thrust faulting.

The positive shift in $\delta^{13}\text{C}_{\text{org}}$ values in the mineralized interval shows strong similarities in both pattern and magnitude to shifts seen in the Aeronian (mid-Llandovery) strata in Arctic Canada and other parts of the world. Although not conclusive, this is consistent with the evidence from published biostratigraphic data that the strata of the main mineralized interval at Howards Pass is primarily Aeronian in age.

Yellowknife – Grays Bay corridor permafrost geohazards mapping

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The Yellowknife-Grays Bay transportation corridor may become a key component for resource and economic development in both the Northwest Territories and Nunavut. Our research goals are to identify permafrost-related geohazards to mineral exploration and development and to anticipate future landscape evolution with permafrost thaw. Knowledge of surficial geology and permafrost is well-synthesized in the south of this corridor within discontinuous permafrost terrain, but remains sparse for the central and northern regions, where till, glaciofluvial sediments, and marine deposits play a key role in terrain stability. Within GEM-GeoNorth, we are collaboratively assessing current and projected permafrost conditions within the corridor region in relation to surficial sediments, geomorphic processes, and a warming climate *via* three foundational activities: i) remote permafrost terrain mapping and synthesis; ii) data-mining to synthesize permafrost knowledge and support mapping and modelling; and iii) regional ground ice modelling.

In summer 2021, we acquired new high-resolution satellite imagery for a 10-km swath of the corridor and adjoining areas with high development potential, and are mapping permafrost-related landforms to determine their associations with surficial geological conditions. These data will support our ground ice modelling, the selection of field sites for future investigation, and validation of ongoing, collaborative, broad-scale thermokarst mapping with our collaborators. We also conducted helicopter-based aerial photo surveys in the corridor in September 2021, which will contribute to synthesis activities.

Borehole data on permafrost conditions are not readily available or compiled for this region. With co-developers at CNGO and NTGS we are compiling geotechnical reports, extracting permafrost data, and making these data accessible through Open Files and databases. This will support our permafrost-landform interpretation and ground ice modelling.

Using a similar methodology to recent national-scale mapping, we are modelling the abundance of segregated, wedge, and buried glacier ice in the region using more detailed surficial geology information from recent Canadian Geoscience Maps. The mapping and data synthesis activities serve to enhance validation of these ground ice model outputs. The modelled regions represent developed and undeveloped terrains, and we are compiling the relevant modelling and validation datasets and developing model refinements for downscaling.

Our results have implications for planning, management, and mitigation strategies on the impacts of permafrost thaw to the development of sustainable transportation and mining infrastructure, and our findings may inform environmental assessments of proposed infrastructure.

This presentation provides an update on our activities and preliminary results.

Developing an integrated environmental monitoring program to detect road impacts along the Dempster-Inuvik-Tuktoyaktuk Corridor

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There is currently a lack in understanding of the impact of Arctic corridor roads on ecological structure and function in sensitive northern streams. Increased sedimentation caused by road erosion during periods of high stream flow and permafrost thaw-driven road slumping have been observed along the Dempster-Inuvik-Tuktoyaktuk Corridor and may pose a threat for aquatic ecosystem services. The objective of this project is to establish stream biomonitoring program along the DITC to study the effects of recent and legacy road development on stream ecosystem health. We

are using Canadian Aquatic Biomonitoring Network (CABIN) protocol, water quality sampling, and studying ecosystem function (*e.g.*, carbon cycling) to implement a multi-faceted approach to understanding the potential impacts to streams by road development and sustained use. With assistance from environmental monitors in the Gwich'in Settlement Area and Inuvialuit Settlement Region, we have tested nationally standardized aquatic biomonitoring protocol and training workshops to produce ecological information that can be used by resource boards to develop management plans to measure impact on aquatic habitat and for future development projects to assess aquatic health and safety concerns.

Late Archean to early Paleoproterozoic tectono-magmatic evolution of the southwestern Rae craton, Northwest Territories, Canada

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There is growing evidence for widespread and voluminous ca. 2.5 Ga magmatism in the Rae craton, but the temporal extent and tectonic setting(s) of this magmatism is unclear. In the Nonacho Lake area of the southwestern Rae craton, we have identified a relatively complete record of ca. 2.54 to 2.43 Ga (meta)granitoid rocks. Based on field relationships, geochronology and geochemistry, these rocks have been separated into two preliminary suites. The first suite is an older group of granitoid rocks that are metaluminous, calc-alkaline and range from 52 to 70 wt.% SiO₂. This suite is characterized by moderate HREE depletion ($La_N/Yb_N = 10-40$) and consistently chondritic initial ϵNd values. The second suite comprises weakly peraluminous leucogranite and local leucotonalite, both with SiO₂ >70 wt.%. These rocks are characterized by strong HREE depletion ($La_N/Yb_N = 50-260$) and initial ϵNd values of 0 to -5. Apart from the leucotonalite, both suites are distinct from Archean TTG (tonalite-trondhjemite-granodiorite) in that they are potassic ($K_2O/Na_2O = 0.6-2.4$) rather than sodic at SiO₂ contents >60 wt.%. One possible explanation for these observations is that the first suite of rocks were generated in a continental arc setting, whereas the second suite of rocks are crustal melts produced during or after orogenic thickening. However, the consistently chondritic Nd isotope composition of the first suite is inconsistent with the mixing and assimilation processes that characterize continental arc magmatism. To test this model, further isotope tracer work is being conducted, along with petrochronology of partially melted metasedimentary and metaigneous rocks that may be coeval with the two granitoid suites.

Geothermal potential of closed underground mines: Numerical study of the Con Mine, Northwest Territories, Canada

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Flooded mines constitute groundwater reservoirs that can be exploited with geothermal heat pumps systems. Modelling such a reservoir is a challenging task because it requires solving the equations of groundwater flow and heat transport within the mine voids having a complex geometry and the surrounding medium, whose hydraulic parameters may have been affected by mining. In this study, we present a tridimensional numerical model developed with COMSOL Multiphysics with the objective of estimating the geothermal heat pump and underground energy storage potential of the Con Mine located near Yellowknife, in the Northwest Territories. This software used the Finite element method to simulate the transient 3D temperature fields within the water and in the rock mass. The shafts and tunnels of the mine are represented with 1D elements embedded in a tridimensional matrix. The thermal and petrophysical properties were evaluated at the mine site and in the laboratory with outcrops survey and core analysis. The numerical model was calibrated to reproduce hydraulic head and temperature measured in one of the shafts while groundwater was pumped out of the mine. Permeability of stopes, shafts and the host rock have been adjusted to fit the pumping data. Then, long-term temperature of the water under different cases of geothermal heat pump

operation was simulated for 25 years. Therefore, it was possible to determine the number of different buildings that could theoretically be heated with the mine water considering the change of building loads affected by the climate. Heat injection in the mine during summer and heat extraction during winter was considered to represent both cooling and heating loads. The total power extracted depends on the depth and flow rate of the pump to be installed in the mine shaft. For a flow rate of 0.06 m³/s, the total power is 3.4 versus 46 MW when the pump depth is 0.3 versus 1 km. The number of buildings to be heated and their surface increase with the power available. We also simulated heat production with solar panels in summer as a mean of energy storage. The advantage to store heat in the ground is to increase the number of buildings to be heated but overall, it may be easier to increase the flow rate or place the pump at greater deep. The model indicates a favourable geothermal potential for the Con Mine. The next step to develop this resource is to design a district heat pump system to exploit the mine water.

GHG Grant Program: An opportunity to lower energy costs and reduce emissions in the mining sector

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Anthropogenic greenhouse gas (GHG) emissions associated with different economic activities across the globe are responsible for a changing global climate system. To take initiatives on the global effort towards climate change mitigation, Canada has recently joined international communities to commit to net-zero emissions by 2050. The Government of Northwest Territories (GNWT) has also set targets to reduce its GHG emissions established in the 2030 Energy Strategy. This document presents a review of overall GHG emissions from the mining sector in Northwest Territories and a case study on the type of energy use and their intensity in different gold mining processes. The historical data shows that the Northwest Territories mining sector emission is increasing at 2 ktCO₂ per year between 2005 and 2019, indicating a need for a rapid annual reduction of 7 ktCO₂ or more to reach its emissions 30% below 2005 level and commit towards the global mining sector net-zero emissions goal by 2050 set out by the International Council on Mining and Metals (ICMM). Diesel and electricity are two main energy sources that contribute to GHG emissions from the gold mining process. Due to the lack of proper grid connectivity, the mining industry in the remote part of the Northwest Territories produces onsite electricity using diesel engines, making it harder to decarbonize. Since environmental regulations including carbon price on industrial CO₂ emissions are getting more stringent, the mining industry must shift towards the production of cleaner products to avoid carbon penalties. Our observation shows that the Northwest Territories mining industry could cost-effectively lower its emissions by promoting wind and solar power, adopting cleaner transport vehicles driven by biodiesel or hydrogen, installing commercial biomass boilers, exploring geothermal energy resources for space heating and power generation, retrofitting for energy efficiency, and promoting waste heat recovery systems. To promote and de-risk these projects and initiatives, the GNWT has been providing grants up to 25% to businesses and individuals under the Buildings and Industry GHG Grant Program. Projects supported through this program not only avoided GHG emissions but also helped businesses and industries to lower their energy costs.

Updates on surficial geology and glacial history of the Birch Lake area, in the Dessert Lake drumlin field, Northwest Territories

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Surficial geology mapping and glacial history reconstruction are essential to drift prospecting, infrastructure development, terrain sensitivity characterization, and baseline geochemical data interpretation. A multi-year initiative is being led by the Northwest Territories Geological Survey to better understand glacial sediment erosion, transport, and deposition history, as well as glacial and post-glacial processes responsible for the heterogeneity and variability of surficial materials in the poorly understood 85K map sheet area.

The focus of the 2020 campaign was to evaluate dispersal patterns potentially associated with aeromagnetic anomalies, as well as to provide a preliminary evaluation of the industrial mineral potential of the area. The 2021 field campaign focused on the till transport history, incorporated a study of drumlin sections, and included regional till sampling to complete the 2020 program. The final collection of 130 till samples includes 30 samples taken to test geophysical anomalies, 24 samples from four distinct vertical stratigraphic sections through drumlins, and 76 samples collected for regional coverage. Till samples are being picked for indicator minerals and analyzed geochemically. Two days were spent on bedrock and striation work up-ice from the main field area to facilitate provenance studies. Several clast fabric measurements were made in the drumlin till sections to further constrain sediment transport history.

Preliminary interpretations of the laboratory results from the 2020 dataset show possible correlations between the till indicator mineral counts and aeromagnetic anomalies. Minerals potentially associated with anomalies include chalcopyrite, sphalerite, scheelite, arsenopyrite, and monazite. Early results suggest long, ribbon-shaped dispersal trains; however, further work, and the incorporation of the 2021 dataset, will be necessary to rule out the possibility of indicator mineral transport from the Slave geological province. Preliminary field observations also confirmed the presence of gypsum as well as abundant angular shale fragments which are key raw materials for cement production.

Field access by helicopter during 2021 was facilitated by lower lake water levels than in 2020, allowing for greater availability of suitable landing sites. New ground observations revealed multiple occurrences of thin, clast-rich, locally derived surficial material and exposed bedrock in a wide swath of land formerly thought to be covered by thick till, crossing the 85K map sheet southeast to northwest. Nonetheless, thick till is actually present in some areas including northwestern 85K, where a major glaciofluvial system cut through thick, continuous till cover. This till, and glaciofluvial system, represents the northern limit of the drumlin field, though high-amplitude 'pristine' drumlins, less affected by postglacial processes, occur only 60 km to the southwest.

Future work will focus on the analysis of transport history and glacial processes in the drumlin field, and the evaluation of the indicator mineral results as they pertain to till composition and post-glacial processes. These projects are the main focus of a newly started master's thesis and an undergraduate thesis, respectively. Both of these projects are taking place at the University of Waterloo.

Preliminary modelling of ground ice abundance in the Slave Geological Province

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New infrastructure corridors within the Slave Geological Province will provide transportation, hydro, and communications links to mineral-rich areas of northern Canada, and connect southern highway systems and Arctic shipping routes. Relatively little information on permafrost and ground ice is available compared to other regions. Ice-rich tills have been observed in the region and preserved buried ice has also been documented within glaciofluvial sediments. Improved knowledge of permafrost and ground ice conditions in the region is required to inform the planning and management of infrastructure. Work within the Geological Survey of Canada's (GSC) GEM-GeoNorth program includes mapping periglacial terrain features, synthesizing existing permafrost and surficial data, and modelling ground ice conditions along the transportation corridor. Here we present initial modelling of ground ice abundance using a methodology developed for national-scale mapping for the Ground ice map of Canada. In contrast with the previous mapping that uses a nationwide surficial materials dataset, we use larger-scale standardized information from GSC Canadian Geoscience Maps (CGM) as model input. We compare outputs for the region derived from the two surficial datasets to assess the influence of surficial geology mapping scale on predicted ground ice abundance. The larger-scale CGM datasets include a greater representation of unconsolidated sediments that may contain ground ice, and consequently, the assessed ground ice abundance is considerably higher than represented on the Ground ice map of Canada. Therefore, estimates from the Ground ice map of Canada should be viewed as conservative for this region and other terrain of the Canadian Shield.

Geology and mining of the Nechalacho rare earth deposits, Thor Lake, Northwest Territories

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Cheetah's Nechalacho rare earth deposits are located at Thor Lake, 110 kilometres southeast of Yellowknife, 8 kilometres north shore of the Hearne Channel on Great Slave Lake. The two principal deposits are the North T deposit, the focus of the current Stage 1 rare earth mining program, and the Nechalacho Tardiff deposit currently in the planning stages for Stage 2 mining.

The North T deposit, at 101,000 tonnes grading 9.01% TREO, consists of a 4-metre thick layer of the light rare earth (LREE) mineral bastnaesite, which occurs in coarse grained to massive aggregates in a gangue of pure quartz. The ellipsoidal sub-zone is one of several concentric mineralogically-distinct zones in the ovoid North-T deposit, which is approximately 150 metres in diameter and 150 metres in depth. The bastnaesite sub-zone crops out on surface and dips inward before flattening out in the centre at an average depth of 30 metres. Open-cast extraction commenced in June of 2021, providing feed-stock ore which was processed by XRT sensor-based ore sorting technology which produced a high-grade bastnaesite concentrate for shipment to Hay River and ultimately to Cheetah's Saskatoon will facility.

Stage 2 will see the development of the much larger Tardiff deposit, one of several high-grade LREE sub-zones in the 94.7 million tonnes Nechalacho deposit. The mineralogy is similar to the North T deposit, consisting primarily of bastnaesite, with sub-ordinate REE minerals monazite and allanite.

Cheetah has off-take agreements with the Norwegian firm REEtec for Stage 1 production of 1000 tonnes REE (ex-Ce)/year for an initial 5-year period, and an MOU with UCore Rare Metals Inc to supply rare-earth concentrate to their planned separation facility in Alaska.

Thermal histories of Cambrian strata and basement rocks from the Great Slave Lake region, Northwest Territories

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The southwest region of the Northwest Territories comprises Phanerozoic sedimentary rocks that cover the Archean-Proterozoic basement. This region is marked by anomalous high heat flow and a geothermal gradient that increases from west to east. The origin of the high heat flow is mostly unknown, and several models have been suggested. We aim to evaluate the origin, source, and longevity of the high heat flow to better understand the potential for geothermal energy production. Towards this aim we use low-temperature thermochronology and thermal modeling to assess the burial and erosion history of the region. The sensitivity window of the (U-Th-Sm)/He system is 55–75°C for apatite and 160–200°C for zircon, thus recording changes in the upper crust. During this first phase of this project, we analyzed basement and the overlying Cambrian strata collected from outcrops and boreholes along the northwestern edge of Great Slave Lake. From the fifteen samples collected, five yielded apatite and nine yielded zircon that are suitable for (U-Th-Sm)/He dating. In general, the (U-Th-Sm)/He single-grain data scatter widely and preclude the reporting of mean sample ages. Apatite single-grain dates range from 16 Ma to 1262 Ma with Cretaceous ages (74 – 143 Ma) being the most common. Zircon single-grain dates range from 59 Ma to 1857 Ma, with Mesoproterozoic ages (1044 – 1579 Ma) being the most common. Due to the thermal sensitivity of the (U-Th-Sm)/He system, detrital data can be considered reset when the sediment was heated to temperatures higher than the partial retention zone (PRZ) after deposition. Most of the Cambrian strata yielded apatite (U-Th-Sm)/He dates that are younger than deposition age and are interpreted to be thermally reset. Two samples yielded single-grain dates that predate and postdate deposition, suggesting partial resetting of the apatite system. The zircon system requires burial and heating

to higher temperatures (>200°C) to be fully reset. Our zircon results show that three samples yielded reset single-grain dates, one sample is partially reset, and five samples are not reset. The partial and total reset samples suggest post-depositional heating to >55°C for apatite and >160°C for zircon. The five sedimentary samples with zircon (U-Th-Sm)/He data that are not reset (older than the depositional age) places a limit to the maximum amount of heating to <160°C. Preliminary thermal modeling of samples that are thermally reset present reheating and cooling after the Cambrian. Most samples record multiple phases of cooling. In total we identified cooling phases during Triassic, Upper Jurassic, Lower Cretaceous and Eocene.

In the second phase of this project, apatite fission track data will be acquired on the same samples to better constraint the thermal history of the samples. The same geo- and thermochronological approach will be applied to outcrop and borehole samples from the western portion of the sedimentary basin in the southwestern corner of the Northwest Territories, including the Liard Basin and the deformation front of the Canadian Cordillera.

Check in with GEM-GeoNorth: Updates and future planning

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GEM-GeoNorth is the latest installment of the Geo-Mapping for Energy and Minerals (GEM) Program, a geoscience research initiative delivered by Natural Resources Canada through the Geological Survey of Canada. The new program, which began in 2020 and will run until 2027, continues to enhance our geological understanding of Canada's North, focusing on areas with high potential for critical minerals and other mined commodities.

GEM-GeoNorth is based on five strong pillars:

1. Refine geological knowledge regarding untapped resource potential in Canada's North
2. Enhance understanding of rapidly changing landscapes and coasts to support economic development *via* critical infrastructure
3. Develop and provide new public geoscience to inform environmental assessments
4. Leverage innovative data-driven predictive methods to forecast cumulative impacts in a changing climate
5. Co-develop research priorities and products with Northerners and Indigenous peoples

Now in the second year of programming, GEM-GeoNorth remains interested in conducting permafrost studies and other complementary geoscience research, with the aim of assessing risks to Northern infrastructure in a changing climate.

And like its predecessors, the newest iteration of GEM continues to engage with an Advisory Group of Northerners, holding bi-annual meetings, as well as with Indigenous communities and organizations to discuss research projects and results. Community engagement is a strong component of the renewed program and our approach to co-development will be discussed throughout the presentation.

The presentation will also cover the many exciting updates that have occurred over the last year:

- First Call for Proposals
- Field work updates for 2022
- How we're aligning our research priorities with Indigenous and Northern governments and organizations
- Launch of our geoscience and multi-disciplinary grants
- Second Call for Proposals

With input from various members of the GEM-GeoNorth team, we will touch on some of the research successes garnered over the past year, and what you can expect from GEM-GeoNorth in the upcoming year and beyond.

Determining gold mineralization style at Salmita Mine, Northwest Territories

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Salmita Mine, located ~240 kilometres north-northwest of Yellowknife, Northwest Territories, produced 179,000 ounces of gold from 1983 to 1987. However, the style of gold mineralization at Salmita is still controversial, with different workers classifying the deposit as either an Archean epithermal deposit or as an orogenic gold deposit. Mineralization is hosted in Mesoproterozoic mafic and felsic volcanics. The majority of gold produced came from a single vein, the B-vein, which is hosted within mafic volcanics crosscut by a major fault and shear zone. Overlying the mafic volcanics is a unit of felsic volcanics that host a lower-grade quartz vein, the T-vein. Gold mineralization is localized in quartz veins and stringers within the mine and is lithologically controlled, with major gold mineralization dominantly occurring in mafic volcanics. Gold mineralization is correlated with sulfide mineral deposition, dominated by pyrrhotite, sphalerite, and pyrite which occur as bands within the B-vein and as disseminated sulfides within the mafic volcanics. Fluid inclusion analyses reveal that high salinity inclusions are present in the veins wherever sulfide mineralization occurs, but are very rare outside of such zones. Additionally, fluid inclusions commonly contain “double bubbles,” indicating high concentrations of CO₂ within the ore zones. Analyses by Raman spectroscopy reveal that the fluid inclusions commonly contain CH₄ and graphite. Together, the presence of CO₂, CH₄ and graphite suggest an equilibrium reaction of the type $CO_2 + CH_4 = 2C + 2H_2O$ was concurrent with gold deposition, which has also been recently documented in other Archean gold deposits in the Yellowknife greenstone belt, such as at Giant Mine. Collectively, these results are broadly consistent with an orogenic style of gold deposition at Salmita.

U-Pb and Lu-Hf characterization of zircon from granites associated with tungsten mineralization, Mackenzie Mountains, Canada

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The Mackenzie Mountains in southeastern Yukon and southwestern Northwest Territories host significant tungsten mineralization, including 10.796 Mt at 1.2% WO₃ at Cantung (combined historic and current estimates), 44.9 Mt at 0.851% WO₃ at Mactung, and 0.75 Mt at 1.17% WO₃ at Lened (Green *et al.* 2020). Mineralization is associated with a narrow belt of crustally derived mid-Cretaceous granite plutons belonging to the Tungsten plutonic suite. Melt source is one of the major controls proposed for tungsten metallogeny; however, the source of fertile magmas spatially associated with tungsten mineralization in the Mackenzie Mountains remains largely unknown due to a lack of exhumation. A second critical aspect for the formation of tungsten mineralization is thought to be the presence of a long-lived fractionating magmatic system capable of concentrating tungsten in the melt and magmatic fluid phases. This study uses magmatic and inherited cores in zircon from plutons belonging to the Tungsten plutonic suite to characterize the U-Pb age and Lu-Hf composition of the evolving magmas and their basement source(s).

Magmatic and inherited cores were identified by SEM-CL mapping of zircon grains then analyzed in a split-stream LA-ICPMS system such that the Lu-Hf and U-Pb isotopic compositions of the cores are determined in-situ simultaneously. The first phase of analyses targeted magmatic cores for several plutons near Cantung, including the Mine Stock pluton underlying the Cantung orebody. Preliminary results are consistent with the hypothesis that the magmatic systems were active for several million years prior to final crystallization. Inherited cores analyzed in the first phase of the study returned Paleoproterozoic to Neoproterozoic ages, although more work is needed to provide inferences on melt and metal source(s). Future analyses will focus on older inherited cores in the Cantung area, as well as magmatic and inherited cores in the Mactung and Lened areas north of Cantung. In addition to documenting the extended crystallization history of the plutons associated with significant tungsten mineralization, this study endeavours to determine the most likely lithological source(s) for the melt and metals in the Cordilleran basement. The results of this work will contribute to our understanding of the framework for the generation of world-class tungsten provinces globally.

Chemostratigraphy of Late Ordovician to Early Devonian strata hosting the Prairie Creek Zn-Pb-Ag deposit, Southern Mackenzie Mountains, Northwest Territories

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The Prairie Creek Zn-Pb-Ag deposit comprises vein-style and stratabound mineralization hosted in Upper Ordovician to Early Devonian basinal strata. This study is designed to characterize the background geochemical signature of the host rocks at Prairie Creek, providing foundational information to support a robust evaluation of geochemical anomalies in regional exploration surveys. Furthermore, geochemical proxies for paleodepositional and diagenetic redox conditions offer relatively new tools for interpreting historically cryptic, fine-grained mudstones. Paleodepositional and diagenetic redox conditions played an important role in the formation of stratabound Zn-Pb mineralization in other districts and a better understanding of these processes could have important implications for exploration strategies in the Prairie Creek area.

To this aim, drill hole PC-10-186 and wedge PC-11-206 were sampled every ~15 m. This deep drill hole constrains the presence of prospective host strata ~2 km from the main Prairie Creek deposit and provides fantastic access to unaltered samples of almost the entire section of host strata. Samples were 15-20 cm in length and targeted homogenous, dark-colored, fine-grained mudstone. Veins and alteration related to minor vein-style mineralization were excluded from samples. Bulk samples were analyzed for multielement geochemistry, $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ composition of carbonates, and total organic carbon (TOC) and hydrocarbon speciation by Rock-Eval pyrolysis.

Preliminary analysis of results shows that the mudstone of each of the four sampled formations (Upper Whittaker, Road River, Cadillac, and Arnica) are characterized by distinct geochemical characteristics. Major element chemistry shows that the contribution from terrigenous detrital material, carbonates (dolomite and calcite), and biogenic silicon varied over time. Redox proxies (e.g., MnO, non-detrital Mo, Ce/Ce*) indicate that the paleodepositional conditions were primarily suboxic to anoxic with the strongest evidence for anoxia and euxinia (free H₂S) in the upper part of the Silurian-Devonian Cadillac Formation. Vanadium is poorly correlated with other redox-sensitive metals, which indicates that concentrations may have been modified by mobilization of hydrocarbons. This is consistent with results from Rock-Eval pyrolysis that show samples are overmatured. Bulk $\delta^{13}\text{C}$ composition of carbonates in the samples fall within the range of expected values for the Phanerozoic and the major excursions correlate well with the $\delta^{13}\text{C}$ curve for strata of similar age in the Richardson trough of the Selwyn basin. Geochemical proxies for hydrothermal alteration indicate limited influence by hydrothermal fluids with Ge <0.1 ppm in all samples and rare positive Eu/Eu* excursions. The strongest positive Eu/Eu* excursion includes four samples with Eu/Eu* > 1.25, spatially correlated with the presence of minor vein-style mineralization.

Modelling the Devonian Horn River Group of central Northwest Territories

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The Middle to Upper Devonian Horn River Group in the central Northwest Territories has been extensively studied by the Northwest Territories Geological Survey (NTGS), the Geological Survey of Canada (GSC), and the energy industry. The resulting datasets, including publicly available well files, survey reports, and outcrop and well sample data, are used in this study for the creation of local and regional geological models. The main objective of this project is to use these models to better understand the regional hydrocarbon system present in the Mackenzie fairway. The models will help to determine how the resource was generated, subsequently migrated, and accumulated at its present location.

The study area includes the Mackenzie Plain Region and adjacent swathes of the Peel Plateau, Peel Plain, Franklin Mountains, and Mackenzie Mountains. For this project 584 wells and 30 outcrops with data were considered as input for the geological models. In the initial phase of the project, well and outcrop data were assessed and those with

insufficient or low-quality data were discarded. In the case of overlapping wells, the most recent well with a full lithological report was selected. The selected data were formatted into point models at the scale of individual wells or outcrops. Lithology for each formation was entered as a percentage of major lithological components (% sandstone, shale, siltstone, *etc.*). For the creation of these local-scale models, certain regional assumptions based on best available knowledge were used, including: timing of unconformities, the total thickness of erosion along those surfaces, and an estimate of the regional heat flow. Based on values from previous research by the GSC, the major regional erosional surfaces are the sub-Cretaceous unconformity (estimated 2.5 km to 3.5 km of erosion), sub-Slater River erosion (135 m), and end Little Bear erosion (75 m). For the regional heat flow, a value of 80 mW/m² was used.

Calibrating the resulting well and outcrop models using maturity data, commonly vitrinite reflectance, has provided reasonable correlations between simulated depth vs maturity curves and sample results. These models will be incorporated into the regional 3-D model, which will be used to simulate hydrocarbon generation, migration, and accumulation. A preliminary build of the geological model using a limited set of local models added to seismic-derived surfaces and a topography map has highlighted important technical issues that will need to be resolved before the full dataset can be added.

Linkages between Paleoproterozoic magmatism and Fe-Oxide mineralization in the Nonacho Basin, Northwest Territories

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The Nonacho Basin is a fault-bound Paleoproterozoic Basin located southeast of Great Slave Lake along the western margin of the Rae Craton of the Western Churchill Province. The basin hosts numerous hydrothermal polymetallic (Cu-Pb-Zn-Ag-U-Th-Mo) occurrences spatially associated with Fe-oxide mineralization (magnetite, hematite) and extensive alkali-calcic alteration (*i.e.*, albitization and potassic alteration). Field investigations by the Northwest Territories Geological Survey (NTGS) recognized that Fe-oxide mineralization is widespread throughout the entire basin, occurring in: (i) the gneisses and granitoids of the Archean-Paleoproterozoic basement, (ii) Paleoproterozoic basinal sedimentary rocks and (iii) Paleoproterozoic alkaline intrusive rocks (*e.g.*, Sparrow and Red dykes, Thekulthili Stock) that crosscut the basin. All aforementioned lithologies are variably replaced by hydrothermal alkali-calcic alteration which appears to be focused along regional structures.

The style and paragenesis of overprinting alteration assemblages have been evaluated using a combination of field observations and μ -XRF (micro-beam X-Ray Fluorescence) elemental distribution maps. The types of alteration identified include early high temperature (HT) sodic alteration (albite), which is overprinted by HT iron-calcic alteration (type-ii magnetite and amphibole), HT potassic-iron alteration (type-iii magnetite and k-feldspar) and low temperature potassic-iron alteration (hematite and sericite).

The Paleoproterozoic alkaline magmatism (*i.e.*, Thekulthili Stock, Red Dykes and Sparrow Dykes) is one of the youngest events and contain primary igneous magnetite (type-I magnetite). The magmatic influx may be a heat engine and possible fluid source for the hydrothermal polymetallic mineralization and alteration of the Nonacho Basin. The association of Fe-oxides with i) widespread alkali-calcic alteration and polymetallic mineral occurrences along regional structures, and ii) alkaline magmatism, is similar to mineralization styles of world class Iron Oxide Copper Gold (IOCG) and affiliated hydrothermal ore deposits. Future work will assess the potential for IOCG style mineralization in the Nonacho Basin by examining the mineral assemblages and trace elements of different Fe-oxides by LA-ICP-MS.

Characterizing groundwater flow within a discontinuous permafrost environment

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Baseline hydrologic monitoring within Canada's northern landscape is of value to the energy sector in advance of oil and gas development and can also elucidate gradual environmental change as a result of climate warming. However, baseline monitoring studies in these regions are complex and expensive to undertake due mainly to limited access, lack of infrastructure and presence of variable permafrost conditions. This is particularly true for the subsurface/groundwater component of the hydrologic cycle. Recent research completed within the Central Mackenzie Valley combined remote sensing techniques with portable field monitoring methods and geochemical/isotope tracing to map regions of groundwater discharge and improve the understanding of groundwater flow characteristics within discontinuous permafrost terrain. Two summer and one winter season field monitoring campaigns were completed within the Bogg Creek Watershed, a small subcatchment southwest of Norman Wells, Northwest Territories. Orbit-based optical imagery provided evidence of recurring icings within the study area suggesting locations of groundwater discharge. Low elevation IR camera surveys conducted during late summer, identified temperature anomalies indicative of cold groundwater discharge. The combined suite of potential groundwater discharge points was selected for helicopter-based terrestrial investigation to measure vertical groundwater flow gradients and to collect water samples for geochemical and isotopic analysis utilizing portable, manual equipment. Physical hydrogeologic data confirmed groundwater discharging conditions with evidence of upward groundwater flow in the shallow subsurface. A range of geochemical and isotopic signatures suggested the existence of several different groundwater sources including water from the shallow active zone and from deeper bedrock aquifers. Surface water and groundwater collected along the length of Bogg Creek illustrated variability in groundwater-surface water interaction and provided evidence of suprapermafrost and subpermafrost groundwater exchange. Establishing clear end-member geochemical/isotopic characteristics is challenging leading to a degree of uncertainty in confirming specific groundwater sources. Although uncertainty remains of exact groundwater origins, the results provide insight into the nature of groundwater flow within a discontinuous permafrost environment. Combining information from remote sensing systems and focused terrestrial monitoring utilizing portable sampling techniques provides a methodology for characterizing aspects of groundwater flow and for establishing priority, long-term monitoring locations without the need for conventional drilling and monitoring well installations. The overall approach would be applicable throughout discontinuous permafrost regions in Canada and elsewhere.

Assessing the temporal and spatial impact of accelerated thermokarst activity on fluvial processes and biogeochemistry within the Willow River catchment, Northwest Territories

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The effects of global climate change are especially acute in permafrost environments of Canada's North. Accelerated changes in temperature and increases in precipitation are resulting in impacts to northern landscapes. Permafrost degradation of ice-rich slopes can result in the development of retrogressive thaw slumps and other types of mass wasting, which can result in the transport of previously frozen materials into nearby aquatic systems. The introduction of these thaw derived materials can have biogeochemical implications at scales ranging from global (the carbon cycle) to local (within-stream ecological function) and can cascade across watershed scales.

The Willow River catchment (near Aklavik, Northwest Territories) has experienced a major increase in thaw-driven geomorphic activity over the past several decades, which has caused the main river channel to divert and deposit sediments within Willow Lake, causing the lake to infill. This project focuses on identifying the biogeochemical changes to the Willow River catchment through a temporal and spatial lens. Specifically, this study aims to understand how the amount and composition of materials flowing downstream have changed over the past several decades as thaw-driven geomorphic activity has accelerated over time, as well as investigating the reactivity and downstream progression of thermokarst-derived materials.

In spring and summer 2021, a team of academics and local land users worked together to collect a series of sediment cores to investigate sediment organic content and composition, as well as mineral composition of terminally deposited materials. A series of cores were collected along a transect towards to apex of the aggrading delta within Willow Lake, as well as along the cut bank of the Willow River that feeds into Willow Lake, the shoreline along Willow Lake, the channel within Willow Lake, and from a series of adjacent lakes connected to Willow Lake. To capture source composition and

infer transformation in-stream, a series of “end-member” samples were collected from eroding thermokarst and landslide features, as well as from streambanks along the Willow River channel. Additionally, bulk water samples were collected to assess changes in water chemistry and suspended materials as they move through the system. All samples collected are currently being processed and analyzed at the University of Alberta. To complement this array of temporal and spatial data, remote sensing analyses are being conducted to understand the evolution of thaw slumps and their impacts on stream networks in the Willow River catchment over the past several decades.

Understanding changes in the reactivity of thermokarst-derived materials as they propagate through fluvial networks will provide insight into how permafrost thaw is impacting the ecological functioning of downstream systems and the degree to which within-stream mineralization of permafrost-derived organic carbon affects the broader carbon cycle. The results of this research will directly impact nearby communities such as Aklavik, Northwest Territories, by providing valuable information on the historic and current effects of permafrost thaw on aquatic systems and water resources, which will integrate with local knowledge of the land to better inform and prepare local communities for future changes in climate.

U-Pb geochronology, zircon mineral chemistry, and litho geochemistry of plutonic intrusions from the Yellowknife greenstone belt, Northwest Territories: Insights into Archean magmatic evolution and the connection to the Townsite Formation and Banting Group

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The Yellowknife greenstone belt (YGB) consists of a north-south trending, near vertically dipping series of mafic and felsic metavolcanic rocks located in the Archean Slave Province of the Northwest Territories, Canada. The YGB has been intruded by several generations of dikes and regional plutons that have not been extensively studied for their magmatic evolution and connections. These include abundant feldspar-quartz porphyry (FQP), quartz porphyry (QZP), and aplite dikes with proximal regional plutons that include the multi-phase Ryan Lake Pluton (RLP), Defeat Suite granite, and Duckfish granite. To date, these dikes have not been definitively linked to a parental pluton and these dikes show litho geochemical similarities to the calc-alkaline Townsite Formation and Banting Group volcanoclastic units.

Thirteen samples were collected from these intrusions and were submitted for mineral separation and litho geochemical analysis. U-Pb geochronology and zircon trace element data were collected concurrently to monitor changes in magmatic chemistry recorded by zircon through time. Five FQP dikes have a range of $^{207}\text{Pb}/^{206}\text{Pb}$ ages, with four concordant ages between 2685 ± 7 Ma to 2629 ± 10 Ma (proximal to the RLP and Defeat Suite) and one upper intercept age of 2770 ± 24 Ma (proximal to the Duckfish Granite). The QZP dike was sampled adjacent to the Duckfish granite and has an inferred $^{207}\text{Pb}/^{206}\text{Pb}$ age of 2763 Ma, based on interpretation of data. Two aplite dikes have concordant $^{207}\text{Pb}/^{206}\text{Pb}$ ages of 2675 ± 13 Ma and 2660 ± 18 Ma. The regional plutons include a tonalite and granodiorite from the RLP, which have concordant $^{207}\text{Pb}/^{206}\text{Pb}$ ages of 2651 ± 8 Ma and 2647 ± 7 Ma, respectively. Two samples were taken from the eastern Defeat Suite granite, one with a concordant $^{207}\text{Pb}/^{206}\text{Pb}$ age of 2580 ± 27 Ma and the other has an interpreted crystallization age of 2579 Ma. Finally, one sample from the Duckfish granite has a concordant $^{207}\text{Pb}/^{206}\text{Pb}$ age of 2576 ± 7 Ma.

The zircon trace element chemistry from these intrusions have distinct rare earth element patterns that show the relationships between dikes and plutons, trends that were also be observed in the litho geochemical data. When all data sets are compared, the results show that the FQP, older aplite dike, tonalite, and granodiorite are genetically related, while the younger aplite dike and Defeat Suite granite are geochemically linked, and the Duckfish granite is related to an undated series of aplite dikes. A comparison of current to historic whole-rock geochemistry of the Townsite Formation and Banting Group shows the separation of two groups. The whole-rock Zr/Hf ratio distinguishes between the granitic samples of the aplite dikes, Defeat Suite and Duckfish granites, and the intermediate FQP, tonalite, granodiorite, Townsite, and Banting Group volcanoclastic rocks. These two groups suggest that only the FQP dikes are genetically related to the Townsite and Banting units as feeder dikes. The spectrum of ages obtained for the FQP dikes also correlates with this conclusion as the dikes were episodically intruding the mafic metavolcanic rocks and progressively formed the calc-alkaline Townsite Formation and Banting Group volcanoclastic rocks.

Analysis of long-term stability of filtered tailings at the Cantung Mine, Northwest Territories, Canada

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Tailings storage is a critical component of the mining process that must be properly conducted in order to mitigate environmental and social impacts. Failures of conventional tailings storage dams have resulted in catastrophic consequences, which have forced a shift in the design thinking of tailings management strategies. Filtered tailings storage involves dewatering and filtering tailings from less than 25% to greater than 80% solids content and is increasingly considered a more environmentally, socially, and economically sustainable option for tailings storage. However, the applicability of this method to potentially acid generating (PAG) tailings remains uncertain because of the potential for environmental harm caused by acid rock drainage. The balance between geotechnical strength and geochemical stability is a critical component of filtered tailings storage design. The water contents of filtered tailings are not high enough to limit oxidation by saturation, so testing the variation in oxidation rates with water content can help to optimize the design. The Cantung Mine, Northwest Territories, is a former tungsten mine currently under care and maintenance. Tungsten is classified as a critical metal in Canada, the USA, and the EU, and the Cantung Mine is considered a world class tungsten deposit based on both grade and tonnage. Production ceased in 2015 with approximately 6.5 Mt of impounded tailings on site. Although static testing indicates that most tailings are PAG, the impounded tailings on the mine site exhibit limited oxidation and pH-neutral pore waters except for the Flat River tailings. Results also indicated that substantial concentrations of tungsten remain in the tailings. This project focuses on geochemical analysis of a filtered tailings storage configuration through column experiments of tailings at different water contents and with different compositions. The range of water contents is based on Standard Proctor Tests, with optimum determined to be 16%. Oxygen consumption, water content and pH have been monitored over 8 months for tailings with initial water contents of 11%, 16%, and 21%. Results show that the rate of oxidation decreases with time after tailings are initially exposed to the atmosphere. While oxidation is occurring, pH appears to remain circumneutral which is expected to be due to the presence of carbonate minerals in the tailings. Reprocessing tests will be conducted to determine if further tungsten recovery and/or sulfide separation is possible. The resulting products from these tests will also be used to investigate variations in geochemical stability. This research will help improve the understanding of how PAG tailings will behave under unsaturated conditions in a filtered tailings stack.

Characterization of rare earth element ore and dissolution rates in near-surface conditions at the Nechalacho deposit, Northwest Territories

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With the addition of rare earth elements to the critical minerals list for Canada, USA and the EU, the importance of a domestic source for Canada has increased significantly. Nechalacho is the only rare earth element (REE) project in production in Canada. In order to extract current and future REE deposits, an understanding is needed of the potential release of harmful elements as a result of mining and weathering processes. The objective of this research is to investigate the dissolution rate and mechanism of the fluorocarbonate ore minerals bastnaesite $\text{REE}(\text{CO}_3)\text{F}$ and parasite $\text{CaCe}_2(\text{CO}_3)_3\text{F}_2$. The results will indicate the possible extent of release of REE's, fluoride, uranium and thorium that have the potential to be released to the near-surface environment during on-site crushing and ore sorting. The Nechalacho deposit, previously known as the Thor Lake deposit, is located approximately 100 km southeast of Yellowknife, Northwest Territories, Canada. This rare earth deposit has mineralization hosted in an assemblage of alkaline syenite and granite with intense hydrothermal alteration. In 2021, a demonstration project extracted ore from the T Zone bastnaesite-quartz-fluorite pegmatite with only physical upgrading of ore on site. For our experiments, we disaggregated pegmatite samples to concentrate the bastnaesite-parasite and ran batch experiments to monitor element release with time to assess

dissolution rates as a function of initial fluid pH. Bastnaesite-parisite concentrate was added to reactors with initial solution pH of 2, 4, and 9 and sampled daily over two-weeks. These results will characterize the reactivity of the bastnaesite-parisite concentrate and shape future experiments to be run in this project. Additional experiments will determine the effect of fluid composition, temperature, grain size, and variation in mineral composition on mineral dissolution rates and rate of REE, U and Th release.

X-ray diffraction (XRD) analysis was utilized to determine the bulk mineralogy of the samples used in the batch experiments. The XRD results confirm the presence of fluorite and quartz in the samples used in the batch experiment, which could not be separated from the bastnaesite and parisite. The electron microprobe analyses of the ore indicate that the bastnaesite contains on average (n = 91) 18.0 wt% La₂O₃, 36.1 wt% Ce₂O₃, and 12.6 wt% Nd₂O₃. The parisite contains on average (n = 53) 13.7 wt% La₂O₃, 28.4 wt% Ce₂O₃, and 10.8 wt% Nd₂O₃. Previous research has focussed on the leaching of REE's from these ore minerals using strong acids at elevated temperature to optimize REE release. This research aims to characterize the ore minerals and provide knowledge of the reaction mechanisms applicable to surface water environmental conditions.

Liard Geothermal Reservoir Project Update

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The Southwestern Northwest Territories has an elevated geothermal gradient, which has resulted in recent interest in the area for research of its geothermal energy potential. Geological data characterizing the reservoir properties of target rocks for geothermal energy development are scarce. The Liard Geothermal Reservoir research program has the main objective to fill this knowledge gap and gather baseline geological data of the prospective reservoir rocks in the southwestern Northwest Territories. The target reservoir rock for this study is the regionally extensive limestone of the Nahanni Formation and its locally dolomitized Manetoe facies. To fulfill this objective, the Northwest Territories Geological Survey (NTGS) and the Department of Infrastructure – Energy Division (INF-Energy) initiated a collaborative research program in 2019.

In phase one of the study, well cores stored at the Core and Sample Repository, Geological Survey of Canada (GSC) in Calgary, Alberta were examined and sampled. Eight wells were selected based on their location and availability of cored Nahanni Formation and Manetoe facies strata, and sampling intervals were defined and approved by OROGO for SR 2019-003. Cores were photographed and described by NTGS. Samples for analysis were collected by AGAT Laboratories (Calgary, AB) under supervision of the Core and Sample Repository, GSC, Calgary. The samples were analysed for porosity and permeability, mineralogy, and pore space characterization.

Phase two of the study comprised field work and field sampling in the summer of 2021 and targeted the same facies that were sampled from core in phase one. A total of 72 samples were collected from a broad region of the southwestern Northwest Territories, including locales west of Fort Simpson from Cli Lake toward the south and west of Nahanni Butte.

This presentation details the results of phase one of the study. The obtained results indicate that reservoir quality is limited through most of the strata, which comprise fine-grained and well-cemented limestone and crystalline dolomite (in the order of 0.01-0.1 mD and <<1 % porosity). Reservoir quality is, however, moderate locally through the stratigraphy, where dolomitization increased vuggy pore space (1 to ~40 mD and 1-7 % porosity). Field observations support the observation of a patchy facies fabric. Additionally, the discontinuous nature of the Manetoe facies was noted in the field; in the southern part of the study area it is thick, well developed and laterally continuous, however toward the north it becomes increasingly discontinuous and only affects the limestone of the Nahanni Formation in discrete, several m to Dm wide lenses. Currently the samples from phase two of the project are being analysed at AGAT Laboratories.

2021-22 Activity Update – Energy Geosciences Group

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The Energy Geosciences group at the Northwest Territories Geological Survey (NTGS) conducts and disseminates energy geoscience studies and data for the Northwest Territories. Since fall 2020, the group advanced work on the following four projects: (1) Shale Basin Evolution in Central NWT, (2) Yellowknife Con Mine Geothermal Potential, (3) Phanerozoic Thermal Evolution of the Southern NWT, and (4) Liard Geothermal Reservoir Characterization. The first three projects support collaboration agreements with academic researchers and their students, and the Liard Geothermal Reservoir Characterization project is supported by the Department of Infrastructure (INF), Government of Northwest Territories.

The objective of the Shale Basin Evolution Project is to characterize the unconventional oil and gas resource in the central Northwest Territories. This project is a collaboration with researchers at the University of Alberta, and is nearing completion with one Ph.D. student in their final year of studies. Jonathan Rocheleau, Energy Geoscientist at NTGS, is developing a 3D basin model as part of this project and preliminary results are highlighted in his presentation at this conference titled Modelling the Devonian Horn River Group of central Northwest Territories.

The Yellowknife Con Mine Geothermal project is a collaboration with researchers at the Institut National de la Recherche Scientifique with the objective to re-evaluate the potential of the Con Mine as a geothermal energy source for district heating in the city of Yellowknife. Promising interim results are described at this conference by M.Sc. student Dan Ngoyo in his presentation titled Geothermal Potential of Closed Underground Mines: Numerical study of the Con Mine (Northwest Territories, Canada).

The Liard Geothermal and Phanerozoic Thermal Evolution projects work in synergy to characterize the geothermal energy potential of the Southwestern Northwest Territories with a focus on the Fort Liard area. The Phanerozoic Thermal Evolution project is a collaboration with researchers at the University of Calgary, and is aimed to assess the thermal history and exhumation of the sedimentary basin in the southern Northwest Territories. Details of this project are discussed by Taís Fontes Pinto in her presentation at this conference titled Thermal histories of Cambrian strata and basement rocks from the Great Slave Lake region, Northwest Territories. The Liard Geothermal project examines the geothermal potential of the reservoir formation; the analysis and characterization work are discussed in the presentation at this conference titled Liard Geothermal Reservoir Project Update.

Last, but not least, the Energy Geosciences group welcomes a new member to the team; we wish to extend a warm welcome to Yaqub Adepoju. Yaqub has an M.Sc. and a Ph.D. in Geophysics, and an M.Sc. in Sustainable Energy Development. Yaqub's expertise is in the areas of oil and gas related geophysical research as well as geothermal energy research, and he brings valuable industry sector experience to the team.

Resource estimation at the Mon Gold Mine – Bulk sampling gold deposits, revisiting an old idea

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Resource modelling of inhomogeneous mineral deposits has evolved over time, now using both enhanced computing power to develop spatial relationships as well as sampling systematics to collect more and bigger samples. Kimberlite-hosted diamond mines have made the collection of large sample sizes as a mechanism to deal with sparse and inhomogeneously distributed minerals of interest common place. High-grade gold mines can also suffer from inhomogeneously distributed gold values, yet with rare instances, solutions historically focus on more small samples and more computer power rather than bulk samples.

A review of three past-producing Yellowknife gold mines is presented to illustrate the distribution of grades in Yellowknife gold deposits. The Discovery Mine 100 km north of Yellowknife produced 3,110 kg of gold from 910,000 tonnes of ore between 1949 and 1969 and is an example of the nuggety nature of gold quartz veins in the Yellowknife Gold Belt. The Con Mine south of the city of Yellowknife produced 186,000 kg of gold from 10,900,000 tonnes of ore between 1937 and 2006 and is an example of shear zone-hosted gold mineralization. Neither had an ore reserve when production started as it was recognized that bulk samples from these promising deposits was required prior to developing a resource. The Mon Gold Mine is located 45 km north of Yellowknife produced 460 kg of gold from 13,600 tonnes of ore between 1990 and 1997. It is currently under development by New Discovery Mines Ltd and Sixty North Gold Mines Ltd and has not got a published Mineral Reserve or Resource.

Contrasts in Northwest Territories community sensitivity to permafrost thaw from broad-scale thermokarst mapping

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Northern landscapes are changing rapidly as a result of climate-driven permafrost thaw, impacting ecosystems and communities. Although broad-scale empirical datasets describing the nature, distribution, and susceptibility to permafrost degradation are crucial to support climate change planning and adaptation, these do not exist for northern Canada. This knowledge gap stimulated the Northwest Territories Thermokarst Mapping Collective (TKC), a project bringing together permafrost and geomatics expertise to develop methods to systematically inventory thermokarst and periglacial landforms around Northwest Territories communities and across the Northwest Territories. Here we synthesize TKC-generated data for over 17,000 km² around 33 Northwest Territories communities (5,625 km² per community) and explore variations and similarities between communities in terms of thermokarst processes and associated impacts. Our assessment draws out regional trends in thaw-driven landscape change and highlights linkages to permafrost conditions, geologic setting, and climate.

For example, large retrogressive thaw slumps occur primarily in mountainous and hilly terrain with ice-rich permafrost, posing a serious hazard to communities and infrastructure in the Tundra Cordillera. Thaw slumps are common in the Tundra Plains as well, although these are constrained in size by geologic and topographic setting, and are found more commonly on coastlines and lakeshores rather than in steeply incised terrain. Deep-seated landslides are observed throughout the Cordilleran but there is a southward increase in cases where the failure plane occurs at the base of thin permafrost, indicating yet another suite of mass wasting processes. Thermokarst lake dynamics are common in extensive areas of low-relief terrain in the Tundra and Taiga Plains and over the Shield. In the Tundra Plains, lake and pond expansion related to polygonal networks and ice-wedge degradation are common, whereas further south in the Taiga Plains, thermokarst lake development and peatland degradation are widespread. The latter occurs over the Shield as well, although to a lesser extent, as organic terrain is less extensive and ramparted lakes are more common thermokarst features.

This sensitivity assessment provides a first quantitative overview of complex combinations of thermokarst processes and thaw-related issues affecting Northwest Territories communities. Identifying overarching trends and community-specific suites of thermokarst landscapes will improve our understanding of the consequences of permafrost thaw, let us prioritize community geohazard mapping, and support climate change adaptation planning.

Snow compaction and the influence on ground temperatures at sites along the Inuvik-Tuktoyaktuk Highway

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The western Arctic is experiencing increasing ground temperatures, active layer thicknesses, and near-surface ground ice melt. Ground ice melt can reduce the integrity of substrate, initiate subsidence and affect infrastructure. Snow cover is an important variable influencing ground temperatures. Thicker snowpack results in higher ground temperatures by limiting ground heat loss and prolonging active-layer freeze back. We conducted a field experiment to examine the influence of snow compaction on the properties of snow, permafrost ground thermal regimes, active layer thickness, and vegetation dynamics, and to assess the general feasibility of snow management. Snow manipulations were completed throughout the winter of 2019/2020 and 2020/2021 at six paired undisturbed and disturbed 50 x 50 m sites across the tree line along the Inuvik-Tuktoyaktuk Highway corridor. Manipulations occurred in December, January, and March; snow depths and densities were collected at the sites before manipulation, and repeated following compaction. Manipulated sites are instrumented with three 2-3 m thermistor cables and several near-surface temperature loggers and paired with control sites where permafrost temperatures are monitored at depth and by an array of near-surface temperature loggers. Manipulations were accomplished using a Snow Cat operated by a local industry partner. Results from the field experiment will help determine whether snow compaction can effectively alter the ground thermal regime by reducing ground temperatures and increasing the rate of active-layer freeze back, and assess the most effective time and environments for snow compaction to occur. This will be completed through an analysis of n-factors comparing the sites and the two years of measurements. Pending experimental outcomes, this method could be applied for use on existing infrastructure, such as road embankments, experiencing permafrost degradation.

Increases in permafrost mass-wasting driven by failure at the base of permafrost in the central Mackenzie Mountain Foothills

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Hillslope mass-wasting in the extensive discontinuous permafrost zone of the central Mackenzie Mountain foothills has significantly increased in frequency and magnitude in the past 15 years. The increase in thaw-driven mass-wasting is largely a function of increasing air and ground temperatures, precipitation, and legacy thermal disturbance from forest fire activity. In contrast to retrogressive thaw slumps, which initiate and develop from the progressive top-down and lateral thaw of permafrost, we identify an increasing frequency and magnitude of deep-seated translational permafrost landslides with failure planes at depths up to 15 metres below the active layer. We identify a suite of thaw-driven processes that involve basal permafrost sliding, thaw-driven fluidized flow, and continued scarp enlargement by retrogressive failure. Thaw-driven detachment of materials at depth produces the capacity to rapidly transport large amounts of frozen material downslope in a blocky manner, often resulting in individual disturbances covering 10s of hectares, and in some instances, damming river drainage. The downstream impacts of rapid large-scale thawing events in this discontinuous permafrost region are not sufficiently understood, but the sediment flux potential is comparable with “mega-slump” thermokarst disturbances. We employ high-resolution satellite and UAV imagery, along with repeat digital elevation models, geological observations, and electrical resistivity tomography surveys to infer that ‘bottom-up’ thaw from the base of the permafrost table is driving the initiation of these features. We present these observations, and put forward a conceptual framework outlining their setting and mechanism of failure at the base of permafrost. Further understanding of the setting and variability of permafrost mass-wasting has implications at all scales, not least of which involves assessing thaw-induced impacts to downstream aquatic systems.

Poster presentations

Presenting author denoted by *

Carbon dynamics and microbial communities associated with winter flow in a lake dominated discontinuous permafrost environment

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The western Canadian subarctic is a landscape in transition due to climate warming, changing streamflow patterns and thawing permafrost. Climate change is mobilizing vast stores of carbon previously held in permafrost and altering the flow of water from land to aquatic systems; these changes should fundamentally affect stream chemistry and ecology. Warming or changing flow regimes can alter the configuration of supra-permafrost taliks, which are pockets of perennially unfrozen ground in a permafrost environment; these have received limited attention for their potential role in facilitating movement of materials in permafrost-affected landscapes. Taliks provide connections between unfrozen areas of the soil during winter, which has the potential to alter the source and chemistry of flow to streams. Across many northern regions, the development and expansion of supra-permafrost taliks in the Taiga Plains and Taiga Shield may contribute to increased winter/spring flow. Although emerging research has documented a unique wintertime chemical signature indicative of talik flow, the specific influence of taliks during different seasons on subarctic rivers is poorly understood. Winter flow through taliks contributes to the development of icings, which are sheet-like masses of layered ice above the ground surface that can be used as an archival tool to study the chemical nature of winter flow. In this study we are investigating the biogeochemical effects of taliks within the River Lake and Baker Creek catchments near Yellowknife, Northwest Territories. We performed detailed water sampling from April to June 2021. In March, we collected ice cores at five icings around River Lake, and an icing along Baker Creek to investigate temporal changes in talik water chemistry over winter. Chemical analyses of water and ice samples is underway and includes measures of DOC concentration and composition, nutrients, major ions, and trace metals. Biological processing is currently being assessed using incubation experiments to determine DOC loss over time. To understand how seasonal changes in water chemistry affect ecological function, microbial community structure will be assessed using 16-S-rRNA techniques. Early results show striking differences in water quality between thawed icing water and open water flow. These results will help inform predictions of how climate warming may change seasonal water chemistry at watershed and larger geographic scales.

Mineralogy and chemistry of V-bearing shales at the Van Property, Mackenzie Mountains, Northwest Territories

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Vanadium (V) is a critical metal with important applications in green technologies and steel production, but is underexplored globally and within Canada. Among the different types of V deposits, those hosted in black shale have so far attracted little attention despite their upside potential. This is partly because of the poor understanding of their genetic processes and mineralogy. Vanadium in the Van Property of the Mackenzie Mountains, Northwest Territories, is hosted in shales with up to 1.6 wt% V₂O₅ (measured by portable XRF). Vanadium mineralization occurs in the Lower Cherty Mudstone Member of the Duo Lake Formation (Road River Group), which was deposited in the Selwyn Basin during the Ordovician to Silurian. This project is designed to investigate the V mineralogy and whole rock lithogeochemistry of a suite of V-rich samples from the property.

Preliminary petrographic observations of hand samples and light and scanning electron microscopy of thin sections show very fine-grained, thinly bedded mudstone with varying graphite content, locally cross-cut by calcite veins. In addition to these methods, samples have been submitted for whole-rock lithogeochemical analysis to determine the composition of the shales including trace element concentrations, total carbon and sulphur, graphite, and organic carbon content. Based on the

available literature, we anticipate results to show a positive correlation between V and organic matter content. Additionally, V-bearing minerals are expected to be silicates rather than oxides due to the reducing nature of the host rock. Anticipated future work will include electron probe microanalysis and hydrocarbon speciation to determine the V-bearing minerals, presence and speciation of organic matter, and their correlation.

Regional assessment of the occurrence of taliks below Arctic lakes

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In continuous permafrost regions, taliks (areas of unfrozen ground) occur mainly beneath large and deep lakes (> 2 m depth) that do not freeze to their bottom. Open taliks connected to regional groundwater can affect the development of mine projects by providing pathways for mine water inflow or contaminant transport. It is therefore important to determine which lakes are potentially underlain by open taliks. A methodology is presented to assess the potential for talik occurrence at a regional scale. The methodology considers lake geometry, lake terrace width, surrounding landscape topography, ground thermal conditions and lake water temperature. Lakes are classified as circular or elongated using GIS analysis. High resolution imagery is used to classify the center pool and the average terrace width of each lake. The ArcticDEM is used to extract topographical variables surrounding lakes to run predictive models of maximum lake depth and to determine if the center pool of each lake is shallow (< 4 m) or deep (³ 4 m) to subsequently attribute a lake water temperature. Lake temperature values for central pools and terraces and the geothermal gradient and ground surface temperature are based on literature values from reports submitted for Environmental Impact Assessments. All parameters are combined in equations defined for circular or elongated lakes in a semi-infinite horizontal plane, with the assumption of steady-state conditions. Ranges of values for lake terrace and ground surface temperatures and geothermal gradient are introduced in equations to cope with uncertainty. This allows classification of each lake as “no open talik”, “potential open talik”, and “open talik”. The methodology is validated with known maximum lake depths, bathymetric contours, and confirmed occurrence of open taliks. Results for mineral resource development areas in Nunavut are provided.

Geophysical data enhancements

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The Northwest Territories Geological Survey holds a large collection of industry and government geophysical data. Assessment reports containing the results of exploration work are submitted to the Government of Northwest Territories by members of the mineral exploration industry under the NWT Mining Regulations (and before April 2014, to the federal government under the Canada Mining Regulations). Submitted assessment reports are released to the public after the period of confidentiality has expired. Early assessment reports contained no digital data, however, starting in the 1980s, geophysical surveys began to appear with assessment report submissions as manipulable digital data. These digital data are available online in the originally submitted form through the Northwest Territories Geological Survey.

The Northwest Territories Geological Survey not only makes the raw data available to the public but is also using the submitted data to create useful products that were not provided in the original assessment report. Examples of these products include grids of calculated parameters; databases in GDB format; merges of adjacent surveys from different assessment reports; and corrections of errors that are found. These enhancements are published as NWT Open Reports. Industry-standard geosoft formats are used, and in addition, new interpretive and original grids are converted into georeferenced tiff images for the user's convenience.

Three-dimensional (3D) magnetic inversion and enhancements of two assessment reports (083838 Benjamin Lake area and 083912 Wecho River area) are presented in the poster. The 3D magnetic inversions are performed to enhance the visualization of structural features and magnetic bodies. 3D Inversion is the mathematical calculation that transforms raw geophysical measurements (in this case magnetics) into a 3D distribution of physical rock properties. In these

enhancements, aeromagnetic data is transformed in a 3D model of magnetic susceptibility below the surface. Geosoft's VOXI module is used to perform the 3D inversion. Input data for the inversion is the residual magnetic field. The inversion was carried out with no constraints and topography is included. These enhancements can be used to provide constraints on the geometrical signature and structural orientation of magnetic sources that could be related to mineralization of interest, especially kimberlite, gold, and VMS occurrences. The complete enhancements methodology (geophysical data enhancement methods with products) and 3D inversions parameters and results will be published as NWT Open Reports in near future.

Permafrost core characterization using gamma ray attenuation and industrial computed tomography scanning

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The physical properties of permafrost cores are largely measured using destructive methods. These approaches are time-intensive and sacrifice critical samples collected at great expense. The development of rapid, non-destructive methods to quantify permafrost physical properties shows great promise but is still poorly developed. In this study, we assess the potential of gamma ray attenuation and industrial computed tomography (CT) scanning to measure physical properties, including density and volumetric ice content, in a range of permafrost cores in the newly developed Permafrost Archives Laboratory at the University of Alberta. We describe the development of calibration standards and individual capabilities for both a GEOTEK multi-sensor core logger (MSCL; including imaging, magnetic susceptibility, non-contact resistivity and gamma density) and a Nikon XTH 225 industrial micro CT scanner. These results are compared with established destructive methods for permafrost-core analyses. The MSCL has a higher throughput capacity and lower cost per metre of core compared with the micro CT scanner. MSCL, once calibrated, shows the potential for processing 10s of metres per day to generate high-quality images, magnetics and density data. Gamma density data is broadly comparable with CT-generated density measurements (derived from linear attenuation of x-rays) but represents a narrow transit of the core compared with the potential for whole core analyses *via* CT scanning. CT scanning still remains one of the most useful tools but is limited by the relatively high costs and time required to image cores. We have found that a combination of MSCL for the rapid characterization of cores, complemented by detailed CT imaging, on a more limited subset of samples including quantitative analyses, provides a useful workflow for permafrost projects.

Linking ice wedge cracking and degradation to catastrophic thermokarst lake drainage

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Ice wedges are a common ground-ice feature in continuous permafrost landscapes, often identified from fields of polygonal terrain. While gradual warming of permafrost has been well-documented across Pan-Arctic landscapes, ice wedge rate of cracking and melt is uncertain, resulting in ambiguities in understanding the effects on surrounding hydrology. Especially pertinent in the western Arctic is the potential influence of ice wedge cracking and melt on "catastrophic thermokarst lake drainage" (CTLTD). This process can completely drain a lake in less than a day when lake water melts a channel through massive ground ice. Mackay (1988) suggests that the primary process for CTLTD is high lake level entering winter cracks through ice-wedge polygons, allowing tunnel flow. This results in wedge ice melt followed by rapid lake drainage. These CTLTD events are important as they drastically alter aquatic environments, impacting fish and wildlife habitat, pose flooding risk to people and infrastructure downstream and impact the broader climate system through changes in lake surface area. Despite the impact on society, ecosystem and global climate, the controls and rate of ice wedge cracking and melt and the subsequent impacts on lake drainage are poorly understood. There is a need to integrate hydrology and permafrost science at the watershed scale through remote sensing of past changes, observations of current conditions and modeling the future of permafrost-lake systems. We have proposed an interdisciplinary research program using high resolution field data for Trail Valley Creek, a study site in the western Canadian Arctic rich in

thermokarst lakes susceptible to drainage. This project will integrate field data with existing high-resolution remote sensing maps of ice wedges around lakes and test, improve and apply high-resolution mathematical models of permafrost-lake-hydrology systems. Specifically, this project aims to better understand the processes controlling CTLD, the importance of ice wedge cracking and melt on lake drainage, the factors that have impacted past lake drainage events, and future changes to ice-wedge polygon degradation and CTLD. We will outline preliminary model development and site selection of this project and upcoming activity. This work will contribute to wider efforts in understanding the impacts of climate change on permafrost and hydrology in the Northwest Territories and across the Arctic.

Mackay, J.R. 1988. Catastrophic lake drainage, Tuktoyaktuk Peninsula area, District of Mackenzie. In Current Research, Part D. Geological Survey of Canada, Ottawa, ON. Paper 88-1D: 83-90.