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Northwest Territories Geological Survey geologist Bernadette Knox with students Valentin Alain and Nancy Ngo studying the Burwash Formation in the Slave Province, Newbigging Lake field area, Northwest Territories.

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Abstracts - Oral Presentations

Presenting author denoted by *

| | |
|---|---|
| BENEFIT AGREEMENTS: DRILLING DOWN ON KEY PROVISIONS ABOUCAR, J. | 1 |
| HYDROTHERMAL HISTORY AND METALLOGENY OF THE NONACHO BASIN ADLAKHA*, E., LANDRY, K., TEREKHOVA, A., HANLEY, J., FALCK, H., and MARTEL, E..... | 1 |
| NWT MINERAL DEVELOPMENT STRATEGY - PROGRESS REPORT 2016-2019 ARCHER, L. | 2 |
| THE INFLUENCE OF BASIN PHYSIOGRAPHY ON THE CHARACTER OF DEEP-MARINE SEDIMENTATION. LESSONS FROM THE NEOPROTEROZOIC WINDERMERE SUPERGROUP, SOUTHERN CANADIAN CORDILLERA ARNOTT, R.W.C..... | 3 |
| VOLCANIC SETTING OF THE SOUTH SUNSET RHYOLITE, BEAULIEU VOLCANIC BELT, SLAVE PROVINCE AUSTIN-FAFARD*, S.B., DEWOLFE, Y.M., PARTIN, C.A., and KNOX, B..... | 4 |
| CURIOSITY PROJECT – AN UPDATE ON A NEWLY ACQUIRED DIAMONDIFEROUS KIMBERLITE BACHYNSKI*, R., SUCHAN, J., and SUCHAN, D..... | 5 |
| PROPERTIES AND ROLES OF BRINES AND HYDROCARBONS DURING SPHALERITE DEPOSITION AT PINE POINT SZMIHELKY, M., BAIN*, W.M., ADAIR, R., FALCK, H., DUFRANE, A., CORLETT, H.J., CAMPBELL, B., and STEELE- MACINNIS, M. | 5 |
| THE MODERNIZED FISHERIES ACT AND THE REVITALIZED FISH AND FISH HABITAT PROTECTION PROGRAM IN A NORTHERN CONTEXT MARTENS, S., BEATTIE*, A., and CURTIS, M. | 6 |
| ECONOMIC OPPORTUNITIES IN NORTHERN MINE REMEDIATION BELLIVEAU, M..... | 7 |
| DIAVIK TRADITIONAL KNOWLEDGE PANEL BERRUB, M..... | 7 |

| | |
|---|----|
| CONSTRUCTING A FINE SCALE PHYSIOCHEMICAL DEPOSITIONAL MODEL FOR DEVONIAN BLACK SHALES: A PETROGRAPHIC STUDY OF THE HARE INDIAN AND CANOL FORMATIONS, CENTRAL MACKENZIE VALLEY, NORTHWEST TERRITORIES BIDDLE*, S.K., LAGRANGE, M.T., HARRIS, B.S., FIESS, K.M., TERLAKY, V., and GINGRAS, M.K. | 8 |
| INVESTIGATING THE NATURE AND ORIGIN OF THE EXETER LAKE ESKER AND ITS APPLICATION IN MINERAL EXPLORATION; A PRELIMINARY REPORT BILAK*, G.S., CUMMINGS, D., and ELLIOTT, B. | 9 |
| COMPARING FEDERAL IMPACT ASSESSMENT TO NORTHERN ENVIRONMENTAL ASSESSMENT BIRCHALL, C.J. | 10 |
| NÍ HADI XA UPDATE E.R. BJORNSON..... | 10 |
| MINERAL EXPLORATION APPLICATIONS FOR LARGE GEOPHYSICAL PROGRAMS SUCH AS THE PAN-CANADIAN EON-ROSE PROGRAM BOGGS*, K.J.E., DARBYSHIRE, F.A., EATON, D.W., UNSWORTH, M., and BENN, K..... | 11 |
| COMMUNITY SCIENCE LIAISON PROGRAM: TRANSFORMING NORTHERN CANADIAN SCIENTIFIC OUTREACH BY CONNECTING K-12 CITIZEN SCIENCE GROUPS WITH EON-ROSE SCIENTISTS BOGGS*, K.J.E., O'CONNOR, K., SHARP, R., CLARK, M., GILBERT, H., DROBOTH, J., and EATON, D.W. | 13 |
| A NEW AEROMAGNETIC COMPILATION FOR THE NWT CORDILLERA REGION BOURKE*, L., UGALDE, H., FISCHER, B., and MIRZA, A.M. | 14 |
| CULTURE DRIVES COMMUNICATION CAUDRON, S.L..... | 15 |
| THAIDENE NĒNĒ NATIONAL PARK RESERVE - EA PROCESS AND QUESTIONS OF DOUBLE STANDARD CHAMBERLAIN, A.G. | 15 |
| SATELLITE OBSERVATION OF DUST ON SNOW AND IMPACT ON SNOWMELT ALONGSIDE UNPAVED MINING HAUL ROADS IN CANADA'S ARCTIC CHEN*, W., HANNA, B., PATENAUDE, A., LEBLANC, S.G., WHITE, H.P., CROFT, B., CLARK, K., PELLISSEY, J.S., JENNINGS, R., GUNN, A., and BOULANGER, J. | 17 |
| TŁIÇHQ GOVERNMENT'S TRADITIONAL KNOWLEDGE GUIDE CHOCOLATE, G.C..... | 18 |

| | |
|---|----|
| GEO-MAPPING FOR ENERGY AND MINERALS: A COORDINATED APPROACH TO ENGAGING INDIGENOUS COMMUNITIES CLARK, K. | 18 |
| A PERSPECTIVE ON THE CURRENT AND FUTURE STATE OF ENVIRONMENTAL IMPACT ASSESSMENT IN THE MACKENZIE VALLEY CLIFFE-PHILLIPS, M.A..... | 19 |
| 13 YEARS OF WOLVERINE SNOW TRACK MONITORING AT THE DIAVIK MINE: WHAT HAVE WE LEARNED COULTON*, D.W., VIRGL, J.A., and SINCLAIR, S..... | 20 |
| WORKING WITH GWICH'IN COMMUNITIES TO DEVELOP A MINERALS & MINING STRATEGY DAITCH, S..... | 21 |
| UPDATE ON RECENT AND PLANNED ACTIVITIES OF THE OFFICE OF THE REGULATOR OF OIL AND GAS OPERATIONS (OROGO) DE JONG*, P. LENNIE-MISGELD*, P. HEPPELLE*, B. MARTIN*, M., and CAMERON*, K..... | 21 |
| RECONSTRUCTION OF THE VOLCANIC AND ORE-FORMING ENVIRONMENT OF THE NEOARCHEAN SUNRISE VMS DEPOSIT, BEAULIEU BELT: IMPLICATIONS FOR VMS FORMATION IN THE SLAVE CRATON DEWOLFE*, M.Y. and KNOX, B. | 22 |
| UPDATE ON THE SLAVE GEOLOGICAL PROVINCE EXPLORATION DEVELOPMENT INITIATIVE – REVITALIZING MINERAL EXPLORATION AND FACILITATING SUSTAINABLE DEVELOPMENT IN A KEY ECONOMIC REGION ELLIOTT, B. | 23 |
| SKARN MINERAL CHEMISTRY AND IMPLICATIONS FOR HIGH-GRADE TUNGSTEN MINERALIZATION IN THE CANADIAN CORDILLERA ELONGO*, V., LECUMBERRI-SANCHEZ, P., LEGROS, H., FALCK, H., and ADLAKHA, E..... | 24 |
| DEFORMATION ALONG THE EASTERN MARGIN OF THE NORTHERN CANADIAN CORDILLERA ENKELMANN, E.E. | 25 |
| RECENT GEOTECHNICAL AND SEDIMENTOLOGICAL INVESTIGATIONS BETWEEN INUVIK AND TUKTOYAKTUK, NWT ENSOM*, T., MORSE, P.D., KOKELJ, S.V., MACDONALD, E., YOUNG, J., TANK, S., GROZIC, E., and CASTAGNER, A..... | 26 |

| | |
|---|----|
| NWT MINERAL EXPLORATION AND MINING OVERVIEW 2019 H. FALCK*, H. ELLIOTT, B., CAIRNS, S., and POWELL, L. | 27 |
| INSIGHTS FROM BEDROCK MAPPING IN THE MACKENZIE REGION, GEM PROGRAM, 2009 TO 2018 FALLAS*, K.M. and MACNAUGHTON, R.B..... | 28 |
| UPDATE ON THE NEW MINERAL RESOURCES ACT: DEVELOPMENT, ASSENT AND NEXT STEPS FARYNA, L. | 29 |
| REGULATORY INITIATIVES FEQUET, R. | 29 |
| 2019-20 ACTIVITY UPDATE – ENERGY GEOSCIENCES GROUP FIESS, K.M. | 29 |
| EXTREMELY LOW FREQUENCY (ELF) PASSIVE EM SURVEY FOR CONDUCTIVITY MAPPING OVER KNOWN SULPHIDE DEPOSITS IN BATHURST, NB FURLAN*, A., UGALDE, H., MORRIS, W.A., and WHITE, D..... | 31 |
| NWT THERMOKARST MAPPING PROJECT GINGRAS-HILL*, T.O.G., KOKELJ, S.V., RUDY, A.C.A., WOLFE, S.A., MORSE, P.D., GIBSON, C.M., BEEL, C.R., and BALTZER, J.L. | 32 |
| TILL PROVENANCE ACROSS GLACIAL LANDSCAPES OF THE LAURENTIDE ICE SHEET IN CENTRAL NUNAVUT AND EASTERN NORTHWEST TERRITORIES GODBOUT*, P-M., MCMARTIN, I., CAMPBELL, J.E., NORMANDEAU, P.X., TREMBLAY, T., and BEHNIA, P. | 33 |
| MINERAL ADMINISTRATION AND REGISTRY SYSTEM (MAARS) GORDON, V.G..... | 33 |
| BURING SHALES AND EXTREME ACIDITY - TOXIC STEW IN THE SMOKING HILLS GRASBY*, S.E., SMITH, I.R., GALLOWAY, J.M., and BRINGUÉ, M. | 34 |
| GROUND SUBSIDENCE AND HEAVE OVER PERMAFROST: HOURLY TIME SERIES REVEAL INTER- ANNUAL, SEASONAL AND SHORTER-TERM MOVEMENT CAUSED BY FREEZING, THAWING AND WATER MOVEMENT GRUBER, S. | 35 |

| | |
|--|----|
| YELLOWKNIVES DENE FIRST NATIONS AND DET'ON CHO CORPORATION AS THEIR ECONOMIC ARM – HOW THEY COLLABORATE EFFECTIVELY GRUNER, S.A..... | 36 |
| LUPIN WINTER ACCESS: PERMITTING ACCESS TO AN EXISTING TRANSBOUNDARY WINTER ROAD CORRIDOR THROUGH NORTHWEST TERRITORIES AND NUNAVUT HAMM, S. | 36 |
| POLYMETALLIC U-NI-CO-AS- AG-BI VEIN DEPOSITS IN THE NORTHWEST TERRITORIES, CANADA: THE PRODUCT OF HEATING AND OXIDATION OF MARINE EVAPORITE BRINES AND METAL-ENRICHED HYDROCARBONS WITHIN CRYSTALLINE BASEMENT HANLEY*, J.J., TROTTIER, C., BURKE, J., OOTES, L., and POTTER, E. | 37 |
| CLASSIFICATION OF HYDROTHERMAL CU-PB- ZN-AG MINERALIZATION IN THE NONACHO BASIN, NORTHWEST TERRITORIES TEREKHOVA, A., LANDRY, K., HANLEY*, J.J., ADLAKHA, E.A., FALCK, H., and MARTEL, E. | 38 |
| POLYPHASE CORDILLERAN DEFORMATION IN THE SELWYN FOLD BELT, NAHANNI REGION, NWT AND YUKON PENNER, B., HICKEY*, K.A., and FALCK, H. | 39 |
| MINING MATTERS: RAISING EARTH SCIENCE AND MINERAL RESOURCES AWARENESS THROUGH PARTNERSHIPS HYMERS, L.A..... | 40 |
| BAFFINLAND'S MARY RIVER HIGH GRADE IRON DEPOSITS, NORTH BAFFIN ISLAND, NUNAVUT IANNELLI, T.R..... | 41 |
| THE FURY AND HECLA GEOSCIENCE PROJECT: OVERVIEW OF THE 2019 THEMATIC RESEARCH ON MELVILLE PENINSULA, QIKIQTAAALUK REGION OF NUNAVUT IELPI*, A., PATZKE, M., GREENMAN, J.W., and HALVERSON, G.P..... | 42 |
| MICROBIAL COMMUNITY FINGERPRINTING AS A TOOL FOR DIRECT DETECTION OF BURIED KIMBERLITES IULIANELLA PHILLIPS*, B., SIMISTER, R.L., WINTERBURN, P.A., and CROWE, S.A. | 42 |
| SPATIOTEMPORAL PATTERNS OF MINING-ASSOCIATED METALS IN SUB-ARCTIC LAKE SEDIMENTS JASIAK*, I., WIKLUND, J.A., TELFORD, J.V. HALL, R.I., and WOLFE, B.B..... | 43 |
| TUNGSTEN MOBILITY IN TAILINGS WATERS, CANTUNG MINE, NORTHWEST TERRITORIES KAZAMEL*, B.G., JAMIESON, H.E., LEYBOURNE, M.I., and FALCK, H. | 44 |

| | |
|---|----|
| ALTERNATE RUNWAY MATERIAL R & D PROJECT KENDALL, R.E..... | 45 |
| NORTHWEST TERRITORIES GEOLOGICAL SURVEY UPDATE FOR 2019 KETCHUM, J.W.F..... | 46 |
| ROADMAP TO MINERAL EXPLORATION & DEVELOPMENT IN THE INUVIALUIT SETTLEMENT REGION KLENGENBERG, C..... | 47 |
| MARIAN WATERSHED STEWARDSHIP PROGRAM BIRLEA, M. and KNAPTON-PAIN*, T..... | 47 |
| UPDATE OF NEW AND ONGOING MAPPING INITIATIVES IN THE SUNSET, NEWBIGGING, AND POINT LAKE AREAS, SLAVE CRATON, NORTHWEST TERRITORIES KNOX*, B., DEWOLFE, Y.M., AUSTIN-FAFARD, S.B., STONE, S.D., ALAIN, V.T.H., and PARTIN, C.A. | 48 |
| IMPLEMENTING AN APPLIED PERMAFROST RESEARCH PROGRAM: THE DEMPSTER–INUVIK TO TUKTOYAKTUK HIGHWAY RESEARCH CORRIDOR KOKELJ*, S.V., RUDY, A.C.A., CONNON, R., ENSOM, T., MORSE, P., VAN DER SLUIJS, J., and WILSON, A..... | 49 |
| LEGAL DEVELOPMENTS RELEVANT TO MINERAL INDUSTRY 2019 KRUGER, T..... | 50 |
| CARBON AND NITROGEN ISOTOPIC SIGNATURES IN THE DEVONIAN CANOL FORMATION: IMPLICATIONS FOR PALEODEPOSITIONAL CONDITIONS LAGRANGE*, M.T., LI, L., KONHAUSER, K.O., HARRIS, B.S., BIDDLE, S.K., FIESS, K.M., TERLAKY, V., and GINGRAS, M.K..... | 51 |
| THE FURY AND HECLA GEOSCIENCE PROJECT 2019: A SUMMARY OF PRECAMBRIAN BEDROCK MAPPING, NORTHWESTERN BAFFIN ISLAND, NUNAVUT LEBEAU*, L.E., RUSSER, M., THERRIAULT, I., and BOVINGDON, P.J. | 52 |
| GSC’S GEO-MAPPING FOR ENERGY AND MINERALS PROGRAM (GEM): RESULTS FROM 12 YEARS OF NORTHERN GEOSCIENCE LEBEL*, D., RICHARD, L., PLOUFFE, M., OZYER, C., IRWIN, S., SHEA, N., and DEHLER, S..... | 53 |
| MOBILITY OF ARSENIC IN MINE IMPACTED SUB-ARCTIC LAKE SEDIMENTS LECLERC*, E.L., TELFORD, J.T., JASIAK, I.J., SCHULTZ, M.S., ENGLISH, M.E., WOLFE, B.W., VENKITESWARAN, J.V., and COUTURE, R-M.C. | 54 |

| | |
|--|----|
| IS THERE A RELATION BETWEEN TUNGSTEN DEPOSIT FERTILITY AND BORON-RICH MELTS? LEGROS*, H., LECUMBERRI-SANCHEZ, P., ELONGO, V., FALCK, H., and ADLAKHA, E..... | 55 |
| GOLD MINERALIZATION AT THE CANTUNG W-CU SKARN: OUR PRESENT LEVEL OF UNDERSTANDING LENTZ*, C.P.E., MCFARLANE, C.R.M., and FALCK, H. | 56 |
| GAHCHO KUÉ MINE UPDATE GOSTLIN, K., BRENTON, K., LIU*, W., and CLARK, L..... | 57 |
| NORTH AMERICA'S LARGEST ICE ROAD - TIBBITT TO CONTWOYTO WINTER ROAD JOINT VENTURE LOWING, M.D. | 57 |
| RECONSIDERING THE BACKBONE RANGES FORMATION, A PROBLEMATIC EDIACARAN- CAMBRIAN UNIT IN THE MACKENZIE MOUNTAINS, NW CANADA MACNAUGHTON*, R.B. and FALLAS, K.M..... | 57 |
| UPDATES TO THE NWT'S PETROLEUM LEGISLATION MARION, J. | 58 |
| IDENTIFICATION OF PHYSICAL AND CHEMICAL PROCESSES IMPACTING WATER QUALITY ALONG THE INUVIK TO TUKTOYAKTUK HIGHWAY (ITH) MARQUEZ*, J.E., KETCHUM, K.Y., and DAY, S.J..... | 59 |
| GEOLOGICAL INVESTIGATIONS OF THE WESTERN MARGIN OF THE SOUTH RAE CRATON, NONACHO LAKE AREA (NTS 75F), NWT: BEDROCK MAPPING, U-PB GEOCHRONOLOGY, METALLOGENY, SEDIMENTOLOGY AND STRUCTURAL EVOLUTION MARTEL*, E., NEIL, B., CANAM, R., ADLAKHA, E., FALCK, H., and IELPI, A..... | 60 |
| LOST BUT NOT FORGOTTEN: RECOVERING AND COMPILING HISTORIC DATASETS TO ADVANCE MODERN EXPLORATION IN THE PINE POINT MINING CAMP, PINE POINT, NORTHWEST TERRITORIES, CANADA. MCDOUGALL*, Z.C. and ADAIR, R. | 61 |
| FROM SCIENCE TO DECISION-MAKING: THE ROLES OF SCIENCE, HAZARD AND RISK ASSESSMENT, AND MITIGATIVE MEASURES IN THE MANAGEMENT OF GEOHAZARDS ALONG THE DEMPSTER HIGHWAY CORRIDOR MCKILLOP*, R.J., ARENSON, L.U., KOKELJ, S., and GIBSON, S. | 63 |

| | |
|---|----|
| LITHALSA DEGRADATION, THERMOKARST DISTRIBUTION, AND LANDSCAPE EVOLUTION, NORTH SLAVE REGION, NORTHWEST TERRITORIES MORSE*, P.D., WOLFE, S.A., and RUDY, A.C.A. | 64 |
| DRIFT PROSPECTING APPLIED TO VOLCANOGENIC MASSIVE SULPHIDE (VMS) AND OTHER GREENSTONE BELT RELATED DEPOSITS EXPLORATION IN THE SLAVE GEOLOGICAL PROVINCE, NT NORMANDEAU, P.X. | 64 |
| LONG-TERM MEASUREMENTS OF PERMAFROST DEGRADATION AND GROUND SURFACE SUBSIDENCE IN THE MACKENZIE DELTA AREA FROM A NETWORK OF THAW TUBES O'NEILL*, H.B., SMITH, S.L., and DUCHESNE, C. | 65 |
| VERIFYING THE PROTECTIVENESS OF A POTASSIUM WATER QUALITY BENCHMARK PACHOLSKI*, L., O'KEEFE, H., and ELPHICK, J. | 66 |
| WALK THE LINE: THE DELICATE BALANCE OF SETTING CLOSURE CRITERIA AND THE RELATIONSHIP WITH CLOSURE/POST-CLOSURE MONITORING PAHL*, D.J., WEEKS, B., and MACHTANS, H. | 67 |
| OVERVIEW OF GEM2 QUATERNARY RESEARCH IN THE SOUTHWESTERN NORTHWEST TERRITORIES: A REGION WITH HIGH POTENTIAL FOR UNDISCOVERED ZN, PB AND CU PAULEN*, R.C., SMITH, I.R., DAY, S.J.A., HAGEDORN, G.W., KING, R.D., SAPERA, J.R., ROSS, M., PIERCEY, S.J., MENZIES, J., DEBLONDE, C., PLAKHOLM, J.A., and PYNE, M.D. | 68 |
| EXTENDED CARE AND MAINTENANCE AND ZERO OCCUPANCY AT SNAP LAKE MINE: AN UPDATE PETERS, M.H. | 69 |
| REMOTE MONITORING AT SNAP LAKE MINE PETERS*, M.H., MENSAH-YEBOAH, F., and MILNE, I. | 70 |
| DEPARTMENT OF INDUSTRY TOURISM AND INVESTMENT RESOURCE DEVELOPMENT OUTREACH ACTIVITIES POWELL*, L. and PADDEY*, M. | 70 |
| CHIDLIAK PROJECT UPDATES PRATHER*, C., MCLEAN, S., and WILLIS, D. | 71 |
| WATER MONITORING AT SNAP LAKE MINE PRATHER*, C., PETERS, M., and MCLEAN, S. | 72 |

| | |
|--|----|
| ASTRO GOLD PROJECT, MACKENZIE MOUNTAINS, NWT PRYER, L.W. | 73 |
| DINÀGÀ WEK'ÈHODÌ; PROPOSED INDIGENOUS AND TERRITORIAL PROTECTED AREA RABESCA*, P., WEYALLON*, T., and CHENEMU*, A. | 73 |
| ZIRCON TRACE ELEMENT AND HF ISOTOPIC COMPOSITION OF GRANITOID ROCKS IN THE EASTERN SELWYN BASIN, NORTHWEST TERRITORIES: A RECONNAISSANCE-SCALE STUDY RASMUSSEN*, K.L. and MORTENSEN, J.K. | 74 |
| SUMMARY OF FINDINGS FOR THE MARIAN WATERSHED STEWARDSHIP PROGRAM, 2013 TO 2019 REDMOND*, M., STEVENS, C., BIRLEA, M., RICHARDSON, S., and KNAPTON-PAIN, T. | 76 |
| CENTRAL MACKENZIE VALLEY BASIN ANALYSIS PROJECT – AN UPDATE ROCHELEAU, J. | 76 |
| TRENDS IN SOCIO-ECONOMIC IMPACT ASSESSMENT AND INDIGENOUS ENGAGEMENT IN THE NWT ROCHON, T. | 77 |
| CHARACTERIZATION OF APATITE WITHIN THE MACTUNG W (CU, AU) SKARN DEPOSIT, NORTHWEST TERRITORIES: IMPLICATION FOR THE EVOLUTION OF SKARN FLUIDS ROY-GARAND*, A., ADLAKHA, E., HANLEY, J., FALCK, H., and LECUMBERRI-SANCHEZ, P. | 78 |
| MULTI-SCALE INVESTIGATIONS TO MAP PERMAFROST LANDSCAPE CHANGE RUDY*, A.C.A., KOKELJ, S.V., LAMOUREUX, S.F., LANTZ, T.C., MORSE, P.D., and VAN DER SLUIJS, J. | 79 |
| NUNAVUT MINERAL EXPLORATION AND MINING OVERVIEW 2019 RUSSER, M. | 80 |
| IMPROVING EXPLORATION SUCCESS IN NORTHWEST TERRITORIES WITH REGIONAL SURFICIAL MAPPING PRODUCTS AND OVERCOMING THE CHALLENGES IN PROVIDING HIGH- QUALITY INFORMATION IN VAST AND REMOTE REGIONS D.A. SACCO*, D.A. and MCKILLOP, R.J. | 81 |
| THE RELATIVE TIMING OF REGIONAL SHORTENING AND PLUTON EMPLACEMENT IN THE SOUTHEASTERN SELWYN BASIN, CANTUNG, NT SALMABADI*, E., HICKEY, K.A., and FALCK, H. | 82 |

| | |
|--|----|
| TRANSPORTATION CORRIDORS AND ACCESS TO RESOURCES IN THE NORTHWEST TERRITORIES SAUNDERS, S..... | 83 |
| TERRAX MINERALS INC. YELLOWKNIFE CITY GOLD PROJECT - DRILLING UPDATE SEXTON*, A., CAMPBELL, J., HEBERT, E., MCALLISTER, B., DUNCAN, S., FINDLEY, A., STOKES, I., BASHYNSKI, R., GABRIEL, D., HARRIS, J., CAMPBELL, S., CLOUGH, A., NAY, K., and SAMSON, B..... | 83 |
| TERRAX MINERALS INC. YELLOWKNIFE CITY GOLD PROJECT - BANTING GROUP VERSUS KAM GROUP GOLD MINERALIZATION SEXTON*, A., CAMPBELL, J., HERBERT, E., STUDD, D., MACKAY, D., CHADWICK, T., STOKES, I., BASHYNSKI, R., GARBRIEL, D., NAY, K., and SAMSON, B..... | 84 |
| DUST IN THE WIND: VEGETATION, SOILS AND DUST DEPOSITION MONITORING AT THE GAHCHO KUÉ MINE SHAPKA*, C., VIRGL, J., and MCLEAN, S. | 85 |
| ACCOUNTING FOR HABITAT DISTRIBUTION IN CARIBOU ZONE OF INFLUENCE: A NEW ESTIMATION USING GENERALIZED ADDITIVE MIXED MODELLING METHODS SHARAM*, G., RETTIE, J., AINSWORTH, L., ZHAO, J., MILAKOVIC, B., O'KEEFE, H., PACHOLSKI, L., and ROCK*, C..... | 86 |
| THE CANADIAN CENTRE FOR CLIMATE SERVICES, A NEW RESOURCE TO SUPPORT NORTHERN CLIMATE CHANGE DECISION MAKING SIEBEN*, B., MURPHY, K., CHENG, L., HOVE, H., and LEE, C. | 87 |
| EVALUATION OF THRESHOLD FREEZING CONDITIONS FOR WINTER ROAD CONSTRUCTION OVER DISCONTINUOUS PERMAFROST PEATLANDS, SUBARCTIC CANADIAN SHIELD SLADEN*, W.E., WOLFE, S.A., and MORSE, P.D. | 87 |
| EVIDENCE FOR SULFUR SATURATION FROM ZIRCON- HOSTED MELT INCLUSIONS IN FELSIC PLUTONS AND DIKES OF THE YELLOWKNIFE GREENSTONE BELT, NWT SPEIGHT*, C., MCFARLANE, C.R., and HANLEY, J.J. | 88 |
| TALTSON HYDRO EXPANSION PROJECT STEWART, A.L. | 89 |
| BEDROCK TOPOGRAPHIC AND TILL THICKNESS CONTROLS ON CONTRASTING TILL DISPERSAL PATTERNS FROM KIMBERLITES, SOUTHEAST OF LAC DE GRAS, NORTHWEST TERRITORIES STIRLING*, R.A., ROSS, M., KELLEY, S.E., ELLIOTT, B., and NORMANDEAU, P.X. | 89 |

| | |
|---|----|
| DIABIK DIAMOND MINE A21 OREBODY Jung, J..... | 90 |
| DEVONIAN SHALE BASIN CHARACTERIZATION IN THE CENTRAL NORTHWEST TERRITORIES – RESULTS OF OUTCROP SAMPLING TERLAKY*, V., FIESS, K.M., and ROCHELEAU, J. | 91 |
| REVISITING THE IMPERIAL FORMATION – PALAEOENVIRONMENTAL RECONSTRUCTION AND POTENTIAL HYDROCARBON PLAY TERLAKY*, V., FIESS, K.M., and ROCHELEAU, J. | 92 |
| WOODLAND CARIBOU WINTER RANGE SELECTION IN THE CENTRAL MACKENZIE VALLEY, SAHTÚ TIGNER, J..... | 93 |
| USING ALTERNATIVE DATA SOURCES TO INFILL AND ATTRIBUTE LINEAR FEATURE DATASETS IN THE NORTHWEST TERRITORIES TIGNER, J..... | 94 |
| EKATI LONG LAKE CONTAINMENT FACILITY (LLCF) RECLAMATION RESEARCH TREFRY*, K. and PETHERBRIDGE, W. | 95 |
| PRECIOUS METALS-RICH VMS MINERALIZATION AT NELSON LAKE, NWT WEBB, D.R. | 96 |
| GETTING AGREEMENTS RIGHT – KEY FACTORS AFFECTING IMPLEMENTATION SUCCESS WEEKES, V. | 96 |
| DIAMOND POLICY FRAMEWORK WELSH*, M. and GILLANDER, A..... | 97 |
| THE CANADIAN MINERALS AND METALS PLAN WESCH, N..... | 98 |
| DECADAL-SCALE FOREST FIRE EFFECTS INTENSIFY RECENT THAW-DRIVEN MASS- WASTING IN THE CENTRAL MACKENZIE MOUNTAIN FOOTHILLS, NWT YOUNG*, J.M., ALVAREZ, A., VAN DER SLUIJS, J., MCPHEE, A., STOKER, B.J., KOKELJ, S.V., MARGOLD, M., and FROESE, D..... | 99 |

Abstracts - Poster Presentations

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| | |
|--|-----|
| INTEGRATION OF SCIENCE INTO LAND AND RESOURCE DECISION-MAKING: A CASE STUDY OF REGIONAL LAND USE PLANNING ADAMS*, J., PHILLPOT, D., PAULETTE, N., HOEFER, H., and STRETCH, V..... | 100 |
| VOLCANIC, SEDIMENTARY, AND DEFORMATION HISTORY OF WINTER LAKE GREENSTONE BELT, SLAVE CRATON, NORTHWEST TERRITORIES: PRELIMINARY RESULTS FROM THE 2019 FIELD SEASON ALAIN*, V.T.H., DEWOLFE, Y.M., KNOX, B., and PARTIN, C.A..... | 100 |
| STRUCTURAL EVOLUTION OF THE WESTERN MARGIN OF THE SOUTH RAE CRATON, NORTHWEST TERRITORIES: PRELIMINARY RESULTS CANAM*, R., GIBSON, H.D., MARTEL, E., and KELLETT, D.A. | 102 |
| TRACE ELEMENT PARTITIONING BETWEEN APATITE AND KIMBERLITE MELTS: IMPLICATIONS TO CRYSTALLIZATION CONDITIONS OF KIMBERLITE MAGMA CHOW*, R., FEDORTCHOUK, Y., and NORMANDEAU, P.X. | 103 |
| FOCUSED FLUID FLOW ON NORTHWEST-ORIENTED FAULTS, BANKS AND VICTORIA ISLANDS, NORTHWEST TERRITORIES DEWING*, K. and MCDANNELL, K.T. | 104 |
| THE EFFECT OF POST DEPOSITIONAL MELTWATER PROCESSES ON KIMBERLITE INDICATOR MINERAL CONCENTRATIONS IN GLACIAL SEDIMENTS DESROSIERS*, P., WARD, B.C., SACCO, D., and ELLIOTT, B..... | 105 |
| MELT AND FLUID INCLUSION SYSTEMATICS OF THE CANTUNG W (CU, AU) SKARN DEPOSIT, NWT, CANADA: MODELING W ENRICHMENT AND FLUID COMPOSITION IN THE ADJACENT MINE STOCK INTRUSION GABRIEL GOMEZ*, G., WAGNER, A., ADLAKHA, E., HANLEY, J., LECUMBERRI-SANCHEZ, P., and FALCK, H. | 106 |
| TOWARD A NEW GLACIAL GEOLOGY FRAMEWORK SUPPORTING GEOSCIENCE APPLICATIONS IN THE SOUTHWESTERN GREAT SLAVE LAKE AREA HAGEDORN*, G.W., ROSS, M., PAULEN, R.C., SMITH, I.R., NEUDORF, C.M., GINGERICH, T., and LIAN, O.B. | 107 |

| | |
|--|-----|
| COMMUNITY SURFICIAL GEOLOGY AND GEOHAZARDS MAP SERIES, FORT MCPHERSON, NORTHWEST TERRITORIES, CANADA MCCUAIG, S.J., KORS-OLTHOF*, R.I., and ROUJANSKI, B..... | 108 |
| PRELIMINARY BENEFICIATION STUDIES OF MACTUNG PHOSPHATE LAMBIV DZEMUA*, G., LI, H., and LIU, Q. | 109 |
| CHARACTERIZATION OF URANIUM MINERALIZATION IN THE NONACHO BASIN, NORTHWEST TERRITORIES LANDRY*, K., TEREKHOVA, A., ADLAKHA, E., HANLEY, J.J., FALCK, H., and MARTEL, E. | 110 |
| APPLICATIONS OF PORTABLE X-RAY FLUORESCENCE ANALYSIS TO EXPLORATION IN THE YELLOWKNIFE GOLD BELT LANGLOIS*, L., LECUMBERRI-SANCHEZ, P., FALCK, H., and SEXTON, A..... | 111 |
| PRELIMINARY BENEFICIATION STUDY OF SELWYN BASIN BARITE ORE LI*, H., LIU, Q., and LAMBIV DZEMUA, G. | 112 |
| PRELIMINARY RESULTS OF SCHEELITE COMPOSITION IN TUNGSTEN SKARN-TYPE AND REDUCED INTRUSION-RELATED GOLD DEPOSITS IN THE TUNGSTEN-TOMBSTONE BELT, CANADA MIRANDA*, A.C.R., BEAUDOIN, G., and FALCK, H..... | 112 |
| NORTHWEST TERRITORIES GEOLOGICAL SURVEY GEOPHYSICAL ACTIVITIES, 2019-2020 MIRZA*, A.M., FISCHER, B.J., and ELLIOTT, B. | 114 |
| MIP DOLLARS AT WORK: A PHOTOGRAPHIC RECORD OF EXPLORATORY WORK ON HIGH GRADE GOLD VEINS ON THE AYE AND HANDLE CLAIMS, YELLOWKNIFE, NORTHWEST TERRITORIES, 2014 TO 2017 NICKERSON, D. | 115 |
| NEW U-PB AGE DATA FOR BASEMENT GNEISSES AND GRANITOIDS IN THE NONACHO LAKE AREA, NT – CORRELATIONS TO THE QUEEN MAUD BLOCK AND TALTSON BASEMENT COMPLEX NIEL*, B., CHACKO, T., HEAMAN, L.M., and MARTEL, E. | 115 |
| RECONNAISSANCE SURFICIAL GEOLOGY, LEITH PENINSULA, NORTHWEST TERRITORIES, NTS 86-E KERR, D.E. and O'NEILL*, H.B. | 116 |
| LONG-TERM STABILITY OF ARSENIC MINERALS IN YELLOWKNIFE BAY SEDIMENTS PAUDYN*, K., CHÉTELAT, J., and JAMIESON, H.E. | 117 |

| | |
|---|-----|
| WILFRID LAURIER UNIVERSITY: PAST, PRESENT, AND FUTURE RESEARCH IN THE NWT RUSK*, B., BEEL, C., WEISS, N., and GINGRAS-HILL, T..... | 117 |
| THE RELATIONSHIP BETWEEN BARREN-GROUND CARIBOU AND WINTER ROADS SMITH*, A. and JOHNSON, C.J..... | 118 |
| PRELIMINARY BEDROCK MAPPING AND LITHOGEOCHEMISTRY OF MAFIC VOLCANIC ROCKS, WINTER LAKE GREENSTONE BELT, SLAVE CRATON STONE*, S.D., DEWOLFE, Y.M., PARTIN, C.A., and KNOX, B..... | 119 |
| A PRELIMINARY RE- EVALUATION OF THE NONACHO BASIN, NORTHWEST TERRITORIES, CANADA: MOTIVATING QUESTIONS AND OVERVIEW OF THE 2019 THEMATIC RESEARCH TULLIO*, M., IELPI, A., FISCHER, B., and MARTEL, E. | 120 |
| CHARACTERIZATION OF APATITE-HOSTED SILICATE MELT INCLUSIONS IN MAGMATIC ROCKS ASSOCIATED WITH THE CANTUNG (W-CU-AU) SKARN DEPOSIT, NORTHWEST TERRITORIES WAGNER*, A., ADLAKHA, E., NEYEDLEY, K., HANLEY, J., FALCK, H., and LECUMBERRI-SANCHEZ, P..... | 121 |
| ENVIRONMENTAL MONITORING OF PLANNED FOREST HARVEST SITES AND NEARBY PERMAFROST TERRAIN IN THE SOUTHERN NWT WEISS*, N., BALTZER, J., OLESINSKI, J., TURETSKY, M., BEEL, C., DIELEMAN, C., SNIDERHAN, A., PAUL, J., and RUSK, B. | 122 |
| TILL GEOCHEMISTRY AND LITHOGEOCHEMICAL EXPLORATION FOR A CONCEALED KIMBERLITE WICKHAM*, A.W., WINTERBURN, P.A., and ELLIOTT, B..... | 123 |
| INFLUENCE OF SNOW COMPACTION ON GROUND TEMPERATURES AT SITES ALONG THE INUVIK- TUKTOYAKTUK HIGHWAY WILSON*, M.A., KOKELJ, S.V., RUDY, A.C.A., and MCALISTER, J..... | 124 |

Abstracts are ordered by presenting author

Abstracts – Oral Presentations

Presenting author denoted by *

BENEFIT AGREEMENTS: DRILLING DOWN ON KEY PROVISIONS

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The new NWT *Mineral Resources Act* requires holders of mineral leases to enter into benefit agreements with Indigenous governments and organizations. While some of the details are yet to be provided through regulations, it is timely to consider key provisions of benefit agreements.

Benefit agreements provide an opportunity to increase Indigenous participation in economic opportunities created by mining. The nature of these agreements has evolved since 1995 with the signing of the first benefit agreement in Canada as Indigenous groups have improved their understanding of, and participation in, the mining industry. While there are typical components in benefit agreements, there are also different approaches depending on the goals of each party, the socio-economic conditions of the Indigenous community and the geologic uniqueness of the mineral deposit.

Drawing on over 15 years' experience in Ontario and in Nunavut, this presentation will provide a typical outline of content of benefit agreements for mines, and will compare different approaches to several key provisions, including: training and employment, business procurement, financial arrangements, implementation, legal certainty and environmental.

This presentation will explore questions that

arise during negotiations. What is the role of targets for employment compared to more flexible commitments? When might sole source commitments work compared to general procurement criteria and practices, or both? How do sharing revenues, sharing profits, fixed payments, and shares stack up as approaches to financial commitments? What is the value of including implementation tools in the agreement? Is there a downside? What are the implications of obtaining Indigenous "support" compared to "consent" for the mine? How can the agreement incorporate on going consultation, weight of Indigenous recommendations, and traditional knowledge?

This presentation will be of interest to Indigenous governments and organizations, mining companies and policy makers.

HYDROTHERMAL HISTORY AND METALLOGENY OF THE NONACHO BASIN

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The siliciclastic Paleoproterozoic Nonacho Basin and underlying crystalline basement rocks host numerous historic mineral occurrences (e.g., Cu, Au, Ag, U). To date, no comprehensive research has been conducted on the Nonacho Basin in order to understand its metallogeny and hydrothermal history, or to assess its potential for economic mineral deposits. This study takes a holistic approach, encompassing the entire hydrothermal system expressed throughout the

basin, as opposed to isolated mineral occurrences, to understand the metallogeny and elucidate the mineral potential of the region. Through combined field, petrographic and microanalytical work, the research will i) characterize the mineral occurrences, including mineralogy, host rock alteration, and structural controls, ii) constrain the timing and paragenesis, iii) elucidate the physico-chemical conditions during each mineralizing event, and iv) classify the mineral occurrences.

Field observations broadly discriminate at least four hydrothermal events characterized by mineralogically and temporally distinct assemblages: i) pink to reddish feldspar-quartz±magnetite, ii) epidote ± hematite, iii) black chlorite ± U, Au, Ag, Cu-sulphides, specular to black hematite, and muscovite, and iv) quartz ± Cu, Zn, Pb, sulfides, Ag, barite, carbonate, and fluorite. These assemblages are ubiquitous throughout the Nonacho Basin, crosscutting all lithologies including basinal siliciclastics, and basement granitoid, gabbro and gneiss. The location of mineralization is structurally controlled by deformation zones, likely initiated as mylonites and overprinted by brittle deformation during later hydrothermal activity.

Feldspar-quartz ± magnetite mineralization occurs commonly as veins (up to 5 cm thick) or broad zones of replacement that extend over a few meters. Pink to red feldspar alteration, and more rarely biotite, along shear zones suggest widespread potassic alteration during early, high-temperature hydrothermal activity and ductile deformation. Broad zones of fine-grained light green epidote alteration are common in areas of mineralization, replacing hydrothermal feldspar as well as host rock minerals (clay minerals, feldspar). The presence of epidote in the basin rocks suggests the introduction of Ca by fluids. The Ca may be sourced from plagioclase of the basement gabbro. It is unlikely that Ca

originated from basin carbonate as that lithology is not dolomitized. Epidote alteration is commonly crosscut by veinlets of coarse-grained black chlorite. This black chlorite is associated with U mineralization, chalcopyrite, bornite and specular hematite near the MacInnis Lake area of the southwestern part of the basin. Historical drillcore assays indicate anomalous Au (up to 0.6 ppm) and Ag (up to 2.5 ppm). Quartz stockwork is characterized by massive, coxcomb and vuggy quartz, which crosscuts the earlier styles of mineralization. It is expressed as multiple generations of orthogonal quartz veins, suggesting multi-episodic hydrothermal activity at shallow levels. In the Crest and Salkeld lake areas, quartz veins are associated with carbonization and fluorite, and late base metal sulfide mineralization.

While it is too early in the research to classify the mineral occurrences, it is noted that the system (and parts thereof) share similarities with IOCG, unconformity-type U, and various base metal vein deposits. Future work will refine the metallogeny of the Nonacho Basin.

NWT MINERAL DEVELOPMENT STRATEGY - PROGRESS REPORT 2016-2019

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This presentation will provide an update on the implementation of the Mineral Development Strategy, a fifteen year plan designed to realize responsible and sustainable development of the mineral resources of the Northwest Territories, now in its sixth year of implementation. The presentation will include an overview of the

strategy, the investments to date and key results achieved. The presentation will also include the next steps to be taken in implementing the strategy as well as key factors influencing the industry that will change how the implementation occurs over the next five years.

THE INFLUENCE OF BASIN PHYSIOGRAPHY ON THE CHARACTER OF DEEP-MARINE SEDIMENTATION. LESSONS FROM THE NEOPROTEROZOIC WINDERMERE SUPERGROUP, SOUTHERN CANADIAN CORDILLERA

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Deep marine rocks of the Windermere Supergroup record a several km-thick sedimentary pile that accumulated along the passive continental margin of Neoproterozoic Laurentia (ancestral North America). The succession comprises mostly siliciclastic sedimentary rocks intercalated with carbonate and mixed carbonate-siliciclastic intervals. Observations along a several 100 km-long depositional transect that stretches from upper slope canyons to deep basin floor deposits show a number of systematic changes, but only in the slope part of the transect.

Slope deposits are dominated by levee deposits intercalated with slope channel

complexes that range up to >100 m-thick by several km-wide, and exhibit two end member kinds of channel fills: aggradational and laterally accreting. Aggradational channels, which individually are of the order of 10-15 m, exhibit a well-developed upward and lateral fining and thinning of strata. In contrast, laterally-accreting channels, which also are ~10-15 m thick, show little upward or lateral change in grain size that on average is also coarser and better sorted than in aggradational channels. Additionally, laterally-accreting channels are associated with the input of carbonate sediment and evidence of more active mass wasting in the form of thickly developed, areally extensive debrites, slump and slide deposits. Moreover, stromatolite and oolite fragments, in addition to abundant carbonate cemented sandstone and mudstone clasts, indicates the resedimentation of debris sourced from an upslope shallow-water carbonate platform under late transgressive, highstand to possibly early falling stage conditions. The eustatic rise that led to the development of the carbonate platform, is also interpreted to have significantly modified the make-up of the siliciclastic sediment supply, principally in terms of its grain-size distribution, which accordingly controlled the density structure in the through-going turbidity currents, and ultimately the character of the slope channel systems. Central to the systematic change in sediment supply is the presence of a topset (i.e., shelf) -- a physiographic feature that is absent in ramp-style basins, and therefore where modification of the hinterland sediment supply would be minimized, and accordingly its influence on turbidity current structure.

Further basinward, basin floor deposits form a succession of intercalated decameter-thick "sheetlike" sandstone and mudstone layers. Sandstone layers are composed mostly of terminal splay deposits with lesser distributary channel complexes and rare feeder channels. Grain size of the sand is little different from that on the slope. Mudstone layers are dominated by

thin-bedded, upper division turbidites. Unlike the slope, the basin floor stratigraphy shows no systematic temporal (i.e., upward) change in architecture. This suggests that the effects of eustatically controlled changes in sediment supply became attenuated and apparently completely filtered as flows descended the continental slope, ultimately resulting in a basin floor stratigraphy largely unaffected by upslope conditions but instead controlled principally by local seabed topography.

VOLCANIC SETTING OF THE SOUTH SUNSET RHYOLITE, BEAULIEU VOLCANIC BELT, SLAVE PROVINCE

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The Sunset Lake area contains Neoproterozoic volcanic rocks of the Beaulieu volcanic belt, which occurs along the northeast margin of the ca. 2.8 Ga Sleepy Dragon Complex ~100 km northwest of Yellowknife. The absolute age and stratigraphy of the volcanic rocks in this belt are not known and thus the volcanic rocks within the Beaulieu belt cannot be easily correlated within the Slave craton. This study focuses on the volcanic rocks, and in particular the rhyolite dome, located at the south end of Sunset Lake and correlating these rocks with those that host the Sunrise volcanogenic massive sulfide (VMS) deposit ~6 km to the north.

The objective of this study is to document the litho- and chemo-stratigraphy of the volcanic strata to determine its petrogenesis and compare it to the volcanic strata that host the Sunrise VMS deposit. Detailed mapping (1:2000) was completed over two summers (2018-2019). The south Sunset Lake area is composed of dominantly massive to pillow basalt and andesite, with lesser amounts of massive to in-situ brecciated, weakly quartz-plagioclase porphyritic rhyolite, heterolithic tuff to lapilli-tuff and felsic tuff to tuff breccia. Felsic clasts are similar in composition to the coherent rhyolite. All units have trace element geochemical signatures typical of modern calc-alkaline arc rocks.

Although originally mapped as a coherent rhyolite dome, the volcanic rocks of the south Sunset Lake area form a more complex stratigraphy consisting of multiple rhyolitic, andesitic, and basaltic lithofacies. Volumetrically, a significant component of the strata consists of volcanoclastic rocks, tuff to tuff breccia units, interpreted to have been deposited by debris flows and eruption-fed density currents. The rhyolite dome and associated volcanoclastic rocks in the south Sunset Lake area are similar in terms of their geochemical signatures and lithofacies to those associated with the Sunrise deposit. While the volcanic strata in the south contain only minor local semi-massive sulfide mineralization at surface, the similarity with host strata for the Sunrise deposit, including evidence of a vent proximal environment (e.g., rhyolite dome) and significant porous volcanic debris on the seafloor, key for replacement of sulfides by circulation of hydrothermal fluids (e.g., thick sequence of volcanoclastic rocks), suggests there is potential for more significant mineralization in the south Sunset Lake area.

CURIOSITY PROJECT – AN UPDATE ON A NEWLY ACQUIRED DIAMONDIFEROUS KIMBERLITE

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The Curiosity Property, located in the Slave Province to the southwest of Contwoyto Lake, is situated ~25 kilometres north of the Ekati Diamond Mine's mineral rights. This newly acquired property hosts a known diamondiferous kimberlite, called "LI-201", which was originally discovered in a 1997 diamond drill campaign. Multiple attempts have been made over the past twenty years to delineate the extent of the body using an assortment of traditional exploration methods, yet LI-201 continues to remain poorly understood in terms of its overall dimensions and diamond-bearing potential.

As part of a ten-day exploration program in August 2019, 275 geochemical till samples and 170 biogeological samples were collected. Geochemical sampling along 100-metre spaced fences that are down-ice and approximately perpendicular to the main ice-flow direction were collected in an attempt to further prioritize key geophysical targets in the project area surrounding LI-201.

In the vicinity of LI-201, geochemical and biogeological samples were collected as a pilot study in an attempt to investigate the potential

microbial community's response to the presence of kimberlite and to determine if a discernable relationship exists between soil geochemistry and microbial populations.

Despite the inconclusive understanding of the kimberlitic body, historical samples of LI-201 show apparent geochemical endowment and bode well for the prospectivity of the project area as a whole. Currently, efforts are being made to compile, verify, and interpret historical data, in addition to integrating newly collected data and interpretations.

At the time of presenting, only preliminary geochemical results will be available; microbiological results are pending. In the future, findings from this study will be used to assess the effectiveness of the microbiological method as a means of detecting the known footprint of LI-201, which may also offer insights to the true footprint of the kimberlitic body.

PROPERTIES AND ROLES OF BRINES AND HYDROCARBONS DURING SPHALERITE DEPOSITION AT PINE POINT

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The chemical mechanisms of lead- and zinc-

sulfide mineralization in carbonate-hosted ("Mississippi-Valley type") deposits is still contentious. Debate has extended over the past several decades, and is still ongoing. Some workers have suggested that mineralization is controlled by acid-base neutralization; others have argued against this interpretation, in favor of redox reactions. Similarly, some workers have interpreted these chemical processes as driven by fluid mixing, whereas others favor fluid-rock reaction as the primary cause.

The Pine Point system, located near Hay River, NWT, is an excellent natural laboratory to investigate these processes. In addition to widespread zinc and lead mineralization, the system shows unique features such as occurrence of bitumen and native sulfur. Using the new samples collected from drill core and from open pits, we investigated the properties of sphalerite-forming fluids at Pine Point in order to gain insight into the origins of the fluids, and the chemical processes that drove mineralization.

The sphalerite crystals from Pine Point commonly contain primary inclusions of aqueous brine, as well as primary hydrocarbon inclusions composed of liquid petroleum and gas. Microthermometry of the brine inclusions shows that they are highly saline brines (~30 wt% NaCl) and enriched in CaCl₂, signatures that suggest derivation from evaporated seawater or fluids that have interacted with marine evaporites. Raman analysis of the petroleum inclusions shows that they contain bitumen and light hydrocarbons. Laser ablation analyses of the brine inclusions shows that they are highly enriched in lead, up to several thousand ppm. The petroleum inclusions, in contrast, contain only trace metals below detection limits. Petrographic analysis shows that both inclusion types (brine and hydrocarbon) were trapped as the sphalerite grew, which in turn

indicates that both metal-rich brine and petroleum were present during the sphalerite deposition.

Together, these observations broadly support a genetic mechanism involving chemical interaction between saline brines and petroleum, and provide new insight into the chemical processes of mineralization in this system.

THE MODERNIZED FISHERIES ACT AND THE REVITALIZED FISH AND FISH HABITAT PROTECTION PROGRAM IN A NORTHERN CONTEXT

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Fisheries and Oceans Canada is the federal lead for managing Canada's fisheries, oceans and freshwater resources. The Fish and Fish Habitat Protection Program (FFHPP) helps conserve and protect fisheries and aquatic ecosystems by conserving existing fish and fish habitat resources, protecting these resources against future impacts and restoring degraded fish habitat.

Changes made to the *Fisheries Act* in 2012 challenged our ability to protect fish and fish habitat. With the modernized *Fisheries Act*, which received Royal Assent June 21, 2019, the

department envisions stronger protections to better support the sustainability of Canada's fisheries. The modernized *Fisheries Act* restores the lost protections providing for protection of all fish and fish habitat and protection against the death of fish, other than by fishing and the harmful alteration, disruption or destruction of fish habitat.

Along with the modernized act, the department is revitalizing the program to build on lessons learned and have increased our capacity in our regulatory review and conservation & protection programs. Additionally, three program groups have been created to enable a better delivery of program outcomes to Canadians. They include an integrated planning group, a provincial and territorial partnerships group and an Indigenous Relations group.

In addition to elaborating on the modernized *Fisheries Act* and the revitalization of our program, the department would like to focus this session on mining projects in the region and the challenges around project impacts and offsetting.

ECONOMIC OPPORTUNITIES IN NORTHERN MINE REMEDiation

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Under Canada's Federal Contaminated Sites Action Plan, the Government has released a new tender, Construction Remediation for Northern Contaminated Sites, that aims to

establish multiple supply arrangements (SAs) for construction services at semi-remote and remote sites in Yukon, Northwest Territories and Nunavut. This tender differs from those available under the Procurement Strategy for Aboriginal Business (PSAB) because these will use limited tendering to benefit suppliers that are local (in proximity) to the location of a remediation project with preference to Indigenous suppliers. In addition to achieving socio-economic objectives, this will save on travel costs associated with completing the work in addition to supporting the local economy.

This seminar is co-presented with the Northwest Territories and Nunavut Construction Association by the Office of Small and Medium Enterprises (OSME), part of Public Services and Procurement Canada. OSME advocates on behalf of Small and Medium Enterprises (SMEs), encourages their participation in federal government procurement, and works to understand and reduce barriers that prevent SMEs from participating in federal government procurement. OSME assists SMEs in better understanding how the GOC buys goods and services, and raises awareness of opportunities to sell to the GOC.

DIAVIK TRADITIONAL KNOWLEDGE PANEL

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Diavik has a robust communities portfolio to ensure that our impacted communities are informed and trusted partners in the success of our operation. The Diavik Traditional

Knowledge Panel has been in place since 2012 as a resource for developing and providing recommendations on a variety of operational and closure details. The Panel is comprised of a male elder, a female elder and a youth from each of the five Participation Agreement communities and, to date, have made 194 recommendations.

Diavik will present on the benefits and opportunities that are created when we utilize traditional knowledge in our operations.

CONSTRUCTING A FINE SCALE PHYSIOCHEMICAL DEPOSITIONAL MODEL FOR DEVONIAN BLACK SHALES: A PETROGRAPHIC STUDY OF THE HARE INDIAN AND CANOL FORMATIONS, CENTRAL MACKENZIE VALLEY, NORTHWEST TERRITORIES

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The Hare Indian and Canol formations, making up part of the Horn River Group (HRG) in the Northwest Territories, primarily consists of organic-rich shales deposited during the Middle to Late Devonian. The formations are considered to represent marine basin fill

accumulated in an oxygen starved distal shelf setting, evidenced by the shale's organic-rich character, pyrite content, and lack of macro-scale bioturbation. This study aims to identify the small-scale fluctuations in both the physical and chemical conditions at and just below the sediment-water interface during deposition.

Detailed petrographic sedimentological and ichnological analyses were carried out on thin sections taken from several cored HRG intervals (MGM Shell East Mackay I-78, Husky Little Bear N-09 and H-64, and ConocoPhillips Mirror Lake N-20 and Loon Creek O-06). These organic-rich shales contain eight distinct microfacies representing three main sedimentation processes: (1) pelagic and hemipelagic suspension settling, (2) combined traction transport and suspension settling, and (3) bedload traction transport. Bedload traction transport dominates in what is interpreted to be the proximal microfacies and is the result of down-slope sediment gravity flows and bottom currents, likely initiated during intermittent or seasonal storms and NW to SE flowing winds. Suspension settling dominates in what is interpreted to be distal quiet waters below storm wave base. Several morphologically distinct microscopic biogenic-sedimentary structures (i.e., ichnofossils) have been identified throughout the HRG mudstones, indicative of sediment pore waters that were at least periodically partially oxygenated. Evaluation of total organic carbon (TOC) content against bioturbation and microfacies interpretation suggest that persistent anoxia was not the dominant factor in organic carbon preservation, but is rather a result of a combination of heightened sedimentation and burial rates and possible amplified rates of primary production.

The depositional model, paleo-oxygenation interpretations, and methods of organic carbon preservation presented in this study are in contrast to previous assumptions of the Horn

River Group mudstones; where such previous interpretations involve a stagnant stratified water column dominated by hemipelagic suspension settling, with organic carbon preservation attributed to persistently anoxic bottom waters. The interpretations presented in this study are likely applicable in other fine-grained organic-rich deposits, where previously anoxia was attributed to high TOC content.

INVESTIGATING THE NATURE AND ORIGIN OF THE EXETER LAKE ESKER AND ITS APPLICATION IN MINERAL EXPLORATION; A PRELIMINARY REPORT

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Eskers are long ridges of glaciofluvial sand and gravel frequently sampled during mineral exploration campaigns. Sampling of the 700 km long Exeter Lake esker by Chuck Fipke and Stu Blusson in the 1980s led directly to the discovery of the Lac de Gras kimberlite field and establishment of the diamond industry in the Northwest Territories. Despite their significant role in mineral exploration, the details surrounding eskers formation remain controversial (e.g., long-conduit vs. short-conduit models). In my coming research I will use a combination of geomorphological and provenance data to gain insight into the nature

of the Exeter Lake esker and the origin of its sediment to help further define the parameters surrounding esker formation and their application in the mining industry.

The geomorphology of the esker will be characterized in ArcMap using (1) the new Arctic DEM (2 m resolution), supplemented by (2) aerial imagery (3) GoPro footage of the entire esker collected during a low-level fly-over, (4) ground observations and short foot traverses made at regularly spaced intervals, and (5) locally collected drone footage. Morpho-sedimentary building block elements of the esker system will be identified and interpreted.

Esker provenance will be studied using two sample suites. The first suite (112 samples) was collected at coarsely spaced intervals (15- 20 km) along the entire length of the esker and contains paired till and esker-ridge samples from both the pebble and finer fractions. These samples will be used to ascertain whether dispersal trains—such as those emanating from the Dubawnt Supergroup—extend the entire length of the esker, considerably overshooting the till dispersal trains from which they were sourced, or whether they are more local in scale. Mud fractions (<63 microns) will be analyzed geochemically; this fraction has never been analyzed previously in similar studies, but could be more indicative of subglacial stream length. Zircon grains from the sand fraction will be analyzed using uranium-lead dating and correlated to diversely aged rock units along the esker system. Finally, the lithology of the pebbles will be analyzed and compared against previously mapped bedrock lithologies along the esker transect.

The second suite (62 samples) was collected at closely spaced intervals (300-600 m) from various geomorphological expressions of the greater esker system near the edge of the Lac de Gras kimberlite indicator mineral (KIM) plume, as defined in the KIDD database. KIM

concentrations from the samples will be compared with one another, and if the KIM train in the esker considerably overshoots that in the till, a long-conduit model may be more likely. Additionally, by comparing multiple expressions of the esker system any bias in the concentration of KIMs should be detected.

Due to the novel approach and large dataset this study has the potential to provide considerable insight into the nature of esker systems and how they are deposited. With this knowledge, mining and exploration companies will be able reassess their esker datasets backed by a scientifically robust exploration model.

COMPARING FEDERAL IMPACT ASSESSMENT TO NORTHERN ENVIRONMENTAL ASSESSMENT

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Following more than 18 months of very heated debates inside and outside Parliament and the Senate, the Impact Assessment Act (IAA) came into force on August 28, 2019, replacing the previous federal environmental assessment regime under the Canadian Environmental Assessment Act, 2012 (CEAA, 2012). Supporting regulations referred to as the Physical Activities Regulations and the Information and Management of Time Limits Regulations came into force on the same day.

The basic structure of the IAA retains elements

of CEAA 2012, including triggering through a Project List or Ministerial designation, four phases (planning, information gathering, assessment, decision), and legislated timelines. However, the IAA contains some key differences such as:

1. authorizing project assessments to consider both positive and negative effects;
2. authorizing project assessments to consider all socio-economic effects, not just all biophysical effects; and
3. introducing a new "public interest" test for project approval.

The presentation will highlight the central features of the IAA and compare them to the environmental assessment provisions set out in the Mackenzie Valley Resource Management Act and the guidelines established by the Mackenzie Valley Environmental Impact Review Board.

The presentation will also provide a similar comparison to relevant provisions in the Nunavut Planning and Project Assessment Act.

NÍ HADI XA UPDATE

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Ní Hadi Xa (NHX, a Denesuline name meaning for "People Watching the Land Together") is a stewardship agreement between Deninu Kué First Nation, Lutsel K'e Dene First Nation, Yellowknives Dene First Nation, North Slave Métis Alliance, Northwest Territory Métis Nation, Thçhò Government and De Beers Canada. The stewardship agreement and its environmental monitoring and traditional knowledge (TK) programs, provide independent input and review on the

environmental management at the Gahcho Kué Diamond Mine. Managed by its Governance Committee, NHX supports six indigenous employees under its capacity building mandate.

Our presentation will include an introduction of NHX and its unique approach in combining scientific and traditional knowledge monitoring. It will also provide an update on the NHX programs, including: Environmental Monitoring, TK Monitoring, and On-the-Land Travel Program.

Environmental Monitoring – This program is undertaken by the NHX Environmental Monitor, stationed at the Gahcho Kué Mine. She works alongside of the mine’s environmental team, collects air, water and soil samples, participates in wildlife observation and monitoring projects, and prepares shift and annual reports back to the NHX. She is also conducting a research project on combining science and traditional knowledge.

Traditional Knowledge Monitoring – The two TK Monitors are stationed at the NHX Cabin, established about 35 km north of Gahcho Kué. During winter and summer months, they use their five senses: sight, hearing, touch, smell and taste, to conduct monitoring of the area surrounding Gahcho Kué based on their knowledge of the air, land, water and wildlife. Their observations and monitoring records are compiled into quarterly TK monitoring reports.

On-the-Land Travel Program – As part of the traditional knowledge program, residents from the NHX signatory communities are sponsored by NHX to travel to the NHX monitoring cabin each summer to live on the land of their ancestors. During the travel program, the residents also participate in the TK monitors’ monitoring routines, share their

knowledge of land, and identify changes of the environment.

The data and reports under the environmental monitoring and traditional knowledge monitoring programs are presented during the routine NHX governance committee meetings for review and discussion. They are also compiled and analyzed by the Environmental Manager, and shared with the NHX Governance Committee and the community members.

MINERAL EXPLORATION APPLICATIONS FOR LARGE GEOPHYSICAL PROGRAMS SUCH AS THE PAN-CANADIAN EON-ROSE PROGRAM

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Projected population pressures and societal demands for environmental sustainability, coupled with the need for carbon-neutral lifestyles to address climate change, require new and innovative strategies for mineral exploration. Projections for 2030 suggest that there will be 280 million electric cars which will require more cobalt, copper and lithium than has ever been produced. Demands for other elements will also continue to increase, e.g., rare

earth elements to support technology and so-called green energy solutions as well as base and precious metals to supply societal and industrial needs. Most easily discovered deposits have already been exploited, meaning that we need to expand exploration into underexplored peripheral “brownfield” environments and also into the remote, geologically poorly understood, underexplored “greenfield” regions where entirely new mining districts remain to be discovered. The unpredictability and expense of greenfield exploration in remote regions requires the adoption of a “Mineral Systems” approach to mineral exploration

The Mineral Systems approach employs a more regional and lithospheric-scale approach than the classic ore deposit scale of previous mineral exploration practices, which has powerful potential applications for regional geophysical programs such as EON-ROSE (Earth-System Observing Network - Réseau d’Observation du Système terrestrE) and EarthScope. Inspired by EarthScope, EON-ROSE plans to install >1400 Earth System Observatories across the Canadian landmass to provide near-real time, open access data. These powered and telemetered stations will include co-located magnetometers GNSS receivers, broadband seismometers, infrasound and pressure sensors, weather packages and permafrost monitors. During the summer of 2019 the first “nested” array (similar in context to the EarthScope FlexArray programs) was deployed at Mt Meager (150 km north of Vancouver, BC) to assess the potential to produce geothermal energy and monitor volcanic activity. In the Canadian context, EON-ROSE is seeking collaboration from the mineral exploration community to justify the significant expense of such a national program, unlike the scientifically motivated NSF funding for EarthScope. EON-ROSE collaboration with industry will also provide valuable

geoscientific results to de-risk mineral exploration programs in remote regions of Canada.

In the southwest US, spatial correlations have been demonstrated between giant/super-giant ore deposits and underlying lithospheric-scale structures, by superimposing maps of such mineral deposits on images from seismic tomography. In the Mineral Systems context, these underlying lithospheric-scale conduits through the sub-continental lithospheric mantle (SCLM) channel ore-forming fluids from the SCLM to form ore deposits within the overlying crust. Densified broadband and nodal seismometer, magnetometer, and gravity sensor deployments for EON-ROSE will outline images of these conductive channels in the SCLM across Canada; ultimately to achieve imaging comparable to that under the giant IOCG-U (iron oxide, copper, gold-uranium) Olympic Dam deposit in Australia. Government-industry-academic mineral exploration collaborations have been very successful in Australia, providing a return on investment ratio of 20:1 through new discoveries such as the Khamsin and Carrapateena copper-gold mines.

COMMUNITY SCIENCE LIAISON PROGRAM: TRANSFORMING NORTHERN CANADIAN SCIENTIFIC OUTREACH BY CONNECTING K-12 CITIZEN SCIENCE GROUPS WITH EON-ROSE SCIENTISTS

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Enabling Canadian kindergarten to grade 12 (K-12) school groups to monitor Earth Systems across Canada themselves will empower and cultivate their passion for the sciences, guiding them to become the scientists of the future. The innovative Community Science Liaison (CSL) program will support this aim by transforming Canadian scientific outreach practices, establishing long-term two-way relationships between kindergarten to grade 12 (K-12) schools and scientific programs such as EON-ROSE (Earth-System Observing Network - Réseau d'Observation du Système terrestre). The CSL concept emerged from the pan-Canadian EON-ROSE research collaboration that was inspired by the serendipitous outcomes from EarthScope to monitor entire Earth Systems across Canada. EON-ROSE will

include ~1400 observatories across the Canadian landmass with broadband seismometers, GNSS receivers, infrasound and pressure sensors, weather packages, riometers, permafrost monitors, etc. that will produce openly available real-time data. The first EON-ROSE station was installed in the Yukon (2018) and a multi-sensor deployment to monitor Mt Meager in the Garibaldi volcanic belt (150 km north of Vancouver, BC) started during the summer 2019. The EON-ROSE collaboration consists of more than 300 scientists from Canadian universities, federal-provincial-territorial government agencies, industry, and international collaborators. The CSL program will use the EON-ROSE connections to network with, and include, other scientific research programs across Canada.

Local community members with a passion for science will be recruited as CSLs from communities across Canada starting in northwestern Canada where there are 36 EarthScope stations. The CSL program will seek to foster scientific curiosity among these northwestern communities, including their Indigenous populations. Many of these communities lack scientists, or even qualified science teachers. CSL training workshops, designed by the scientists, will run concurrently with EON-ROSE conferences (starting with the EarthScope transition to EON-ROSE meeting May 2020). Scientists from EON-ROSE and other programs will provide mentorship, enabling CSLs to lead community consultations while designing and guiding hands-on, place- and curriculum-based K-12 Citizen Science projects to address community curiosity or concerns. The Geological Bumble Bee (GBB; Figure 1) program is an example of a Citizen Science program that will expand under the CSL umbrella, to permit these K-12 groups to monitor these important pollinators, which are under threat due to climate change. The GBB program (2012 to present) has involved ~800 Calgary grade 2-9 students building and

installing ~800 bumble bee boxes while concurrently collecting rocks to characterize the glacial material deposited by glaciers ~15,000 years ago. These students return to the field in the fall to collect their boxes and analyze the bumble bee colonies that occupied their boxes. K-12 Citizen Science groups will be invited to present their results at the annual EON-ROSE conferences – completing the research cycle.

Place- and curriculum-based CS projects were proven by the Wood Street School (Yukon) to be very successful at engaging high school students in the northern Canadian context – 100 % of these students graduated from high school and 60% pursued STEM post-secondary programs. This speaks to the potential for this CSL program to make scientists household names.

A NEW AEROMAGNETIC COMPILATION FOR THE NWT CORDILLERA REGION

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At a regional scale and for the purpose of delivering base geological cartography, federal and provincial government agencies plan and commission aeromagnetic surveys over blocks that are of higher priority at the time of planning. Airborne magnetic surveys are a part of the reconnaissance work for projects and cultivate a patchwork of different sized surveys. The difference in sizes between surveys creates a patchy effect in the

combined data. This results in a block-style distribution of surveys that were flown with different acquisition parameters such as platform, flying height, line spacing and line orientation.

The advantage of compiling these individual grids into a single grid is to provide a consistent portrayal of the geophysical response of the imaged rock. This facilitates interpretation of the data for the end users, who can now look into a single file instead of having to browse, clip and display multiple blocks.

The varying sensor height of the multiple surveys will be a challenge for any compilation effort, since surveys flown higher will register a weaker signal than those at lower elevations. One approach to account for this is to level the high-resolution surveys up to the flying height of more regional surveys (upward continuation). The second possibility is to compromise at an intermediate flying height between the regional and detailed surveys, and level all the data to that level. A third possibility is to bring all the surveys to the lowest possible height. Downward continuation methods have the potential to introduce noise that obscures geological signal while upward continuation methods have the potential to lose signal but have greater computation capacity. For all these approaches, there are a variety of computational procedures that could be used.

This project will use a draping downward continuation on profile data to create a compilation of aeromagnetic data available for the NWT Cordillera. There were 18 government surveys flown between 1961 and 2018 by both the GSC and NTGS, with flying heights ranging from 110 to 2000 m and line spacings between 400 and 1207 m; and 2 industry surveys flown between 2006 and 2011, with line spacings between 100 and 300 m and 100 m flying height with variable line orientation. Using the radar altimeter data to calculate the downward

continuation distance, profile data from all the surveys were draped line by line to the lowest possible elevation by using a Taylor expansion. The height-corrected profile data were gridded and microlevelled and resultant grids were compiled. The final levelled grid will be published in the NWT Open File series.

A further goal is to refine the structural map of the area. The current geological maps for the region are a mixture of 1970's reconnaissance work that has been digitized and reinterpreted, 1:250,000-scale maps based on 1980's mapping, and 1:100,000 scale maps of selected areas from the 2000's. Interpreted faults and folds from the aeromagnetic data will be validated and refined using the available bedrock geology along with publicly available radiometric data.

CULTURE DRIVES COMMUNICATION

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Culture drives communications in the North! To promote economic growth, sector development and innovation in the mining industry, the Mine Training Society (MTS) is proposing to increase the number of Northwest Territories' and Nunavut residents working in the mining industry. To strengthen MTS capacity and to better serve our northern communities, MTS will be implementing a new communications strategy "Connecting Our Communities". This new strategy will have a role model campaign, a social media strategy, and more importantly community consultations and stakeholders' meetings. By expanding and enhancing current programs MTS is better able to meet the industry

demand for skilled workers. MTS has developed more programs to meet the needs of mine start-up, operations and reclamation.

MTS will be scheduling community consultations across the North to listen to residents on what they want, how we can better serve them, promote careers in mining, educate on MTS programs and recruit participants. Stakeholders meetings will be held once per year at the end of April, with a conference tentatively scheduled for 2021. Our focus is to provide community support and deliver expert training to our smaller communities in order to promote skill development of Northerners

The Mine Training Society has two new proposed training to employment strategies under the Employment and Social Development Canada, Youth Employment and Skills Strategy. The funding for these programs is specific to youth, 18-30 years, targeting women, youth at risk, Indigenous youth and new to Canada youth. "Beginning to End" is an industry-driven strategy specific to the Northwest Territories, with some of the training rotated to various communities. "Resources North" is a national strategy in partnership with the Kitikmeot Inuit Association, Nunavut and North Island College, British Columbia.

THAIDENE NĒNĒ NATIONAL PARK RESERVE - EA PROCESS AND QUESTIONS OF DOUBLE STANDARD

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The federal government appears not to have complied with its own environmental

assessment process before it established a 33,360 km² protected area in the NWT. The area, Thaidene Nënë National Park Reserve, Territorial Protected Area and Wildlife Conservation Area, was formally proclaimed as a National Park Reserve on August 21, 2019.

Thaidene Nënë is a jointly protected park reserve by the federal and territorial governments together with the Łutsël K'é Dene First Nation, who consider it to be the 'heart of the homeland' and a sacred place. It consists of a 14,305 km² National Park Reserve protected by Parks Canada as well as 12,220 km² of territorially protected areas and wildlife conservation areas. The park is considered an Indigenous Protected and Conserved Area, and the Łutsël K'é Dene will serve as its stewards.

Proposed developments in the region must apply and go through the environmental impact assessment process pursuant to the Mackenzie Valley Resource Management Act. The Act states that no authorization for the carrying out of development shall be issued,

“under any federal, territorial, Tliche or Déline law unless the requirements ... have been complied with ...”

The environmental assessment process begins with a preliminary screening, which is a review by a regulating authority, in this case, Parks Canada. At this stage, the preliminary screener is required to apply the test pursuant to the Act:

1. Might the development proposal cause significant adverse impacts on the environment?
2. Might the development proposal be a cause of public concern?

If answered in the affirmative, the Act requires

that the application is referred to the second-stage of the review process, an environmental impact assessment that is handled by the Review Board.

The Thaidene Nënë preliminary screening began April 5th, 2019. Within a month, Parks Canada received thirteen comments about the development, some raising concerns about the impact of the park on economic activity and the closing of mineral rich lands to exploration.

On July 5th, 2019, a decision was released by Parks Canada not to refer the park to the Review Board for an environmental assessment

The preliminary screening closed two weeks after the decision was made by the federal government to give Royal Assent to the creation of Thaidene Nënë, which created the park.

The Review Board did not order an EA and it noted that the preliminary screening process conducted by Parks Canada was inconsistent with the Act as irrevocable decisions to proceed had already been made. The Review Board stated that while it might be theoretically possible for Parliament to reverse or repeal its decision to create the park, such an action was “effectively impossible.”

This presentation will discuss the process and competing views on the validity of the process in light of the decision of the Review Board, the legal requirements to which the government is itself subject to and the involvement of Łutsel K'e Dene First Nation in the park creation process.

SATELLITE OBSERVATION OF DUST ON SNOW AND IMPACT ON SNOWMELT ALONGSIDE UNPAVED MINING HAUL ROADS IN CANADA'S ARCTIC

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Improved monitoring of dust on snow from mining activities in the Arctic and its impact on spring snowmelt is proposed as one component of a dustfall standard for environmental assessment presently being developed by the Government of the NWT, Department of Environment and Natural Resources (ENR). Observations of earlier spring snowmelt along mining haul roads have been locally reported, but not consistently documented. Dust on snow along these roads could affect local snowmelt, vegetation growth and distribution, hydrological process, and permafrost dynamics, and provide positive feedback to climate change globally.

With funding from the NWT Cumulative Impact Monitoring Program (NWT CIMP), our

project investigated the feasibility of using satellite remote sensing for quantifying dust on snow and its impact on snowmelt. First, we investigated the temporal dynamics of dust on snow snowmelt along unpaved haul roads around the Ekati Diamond Mine using MODIS data with daily coverage since 2000. The MODIS data fits well with that of the Ekati Diamond Mine development, which started construction in 1998 and operations in 2003. While the spatial extent of dust on snow could be detected using MODIS, its 250-m spatial resolution limits map accuracy. To improve accuracy, we further investigated 30-m Landsat data to quantify the spatial extent of dust on snow and its impact on snowmelt.

Initial results indicated that clean snow and dust-contaminated snow can be clearly separated using satellite data, with a visible spectral reflectance (albedo) ranging from ~0.9 for fresh clean snow to ~0.6 for packed clean snow, against only ~0.2 for dust-contaminated snow. The separability reduces when clean snow starts to melt (albedo = ~ 0.4), especially where bare tundra without snow cover (albedo = ~0.1) also occurs. Dust on snow appears to accumulate in detectable levels starting in March, and usually ends in May or early June along the Ekati Diamond Mine haul roads. In most cases, the spatial extent of dust on snow and resultant observable earlier snowmelt occurred within 1 km from the road. However, in several cases, a continuous field of dust on snow could be detected up to about 2 km from the haul roads. Other sources of dust on snow were also detected further away from roads, potentially related to exposed natural sources such as eskers.

The spatial extent of dust on snow detected in this study compare well with direct dustfall measurements (~ 1 km), and the gradients of dust on leaves measured in situ (and supported by spectral satellite observations) and soil pH measured along the distance from the road (~

1.5 km). The snow and lichen chemistry analyses also showed that “many of the highest concentrations occurred within 1 km of roads.” However, the snow and lichen chemistry analyses also found “many elements from the various sampling locations were above background levels within 10 to 30 km from the mine site”. Further investigation is needed for better understanding the reason for the enhancement of element levels within 10-30 km from the mine.

TŁJCHQ GOVERNMENT'S TRADITIONAL KNOWLEDGE GUIDE

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The Tłjchq Government's Department of Culture and Lands Protection is preparing a traditional knowledge policy to implement guidelines for those who wish to work with Tłjchq traditional knowledge. The traditional knowledge research team will be introducing the draft policy at the Geoscience Forum to spread public awareness of its interpretation and application. The traditional knowledge policy provides clear guidance for key individuals and groups who wish to work within Tłjchq lands. As outlined in the Tłjchq Agreement, Tłjchq people have the right for their voice and traditional knowledge to be included in any matters that pertain to them. This policy is to be implemented in all matters involving Tłjchq elders and knowledge holders and applies to government bodies, organizations, businesses, researchers and industry.

This policy is being put in place to ensure that Tłjchq traditional knowledge is consistently used in an appropriate manner that respectfully and accurately reflects Tłjchq elders and ancestors. The Tłjchq nation owns all their traditional knowledge, the usage of which is to be directed by the Tłjchq Government.

GEO-MAPPING FOR ENERGY AND MINERALS: A COORDINATED APPROACH TO ENGAGING INDIGENOUS COMMUNITIES

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The Geo-Mapping for Energy and Minerals (GEM) program is the Government of Canada's \$100 million initiative to significantly improve the geoscience of the Canada's North. GEM activities provide the fundamental, regional geoscience knowledge that northerners and industry can use for land use planning and responsible resource development decisions. With northern energy and mineral resources potentially being as abundant as those in the South, an opportunity exists to create prosperity for Northerners by supporting the development of a sustainable, vibrant northern economy.

GEM activities target areas of the North where critical geoscience knowledge gaps exist. The data and knowledge collected by GEM activities are all made available to the public at no cost. By accessing and using the knowledge GEM produces, northerners and industry are better positioned to balance resource development with other considerations when they

collectively develop policies and make investment and sustainable land use decisions.

The GEM program leverages its constitutionally required duty to consult indigenous peoples to achieve program objectives. Strategic engagement of Northerners through the GEM program is occurring through innovative approaches, such as by soliciting advice from our Advisory Group of Northerners, by launching a multidisciplinary grant call and by undertaking engagement with communities across the North throughout a project's lifecycle – before, during and after field work occurs. Community visits are an opportunity to discuss the history of the local geology and preliminary activity results with community members and these experiences can help them be engaged and active in decisions affecting land-use and resource development.

The program is building on lessons learned throughout the years and works with northern collaborators to explore new opportunities for collaboration that increase relevance and accessibility of GEM results to Northerners. As the program moves towards its sunset in March 2020, a coordinated approach to in-person reports of results is being undertaken. This is a direct result of listening to the needs of communities, who overwhelmingly requested in the consultation phase that GEM staff return after fieldwork to report back on results in a non-technical fashion, so that Northerners may learn more about their lands, and become active users of the GSC's information.

A PERSPECTIVE ON THE CURRENT AND FUTURE STATE OF ENVIRONMENTAL IMPACT ASSESSMENT IN THE MACKENZIE VALLEY

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The Mackenzie Valley Environmental Impact Review Board (Review Board) has worked hard to be known as a leader and innovator in the field of impact assessment. In recent years, there have been several initiatives to review and evolve the federal, territorial, and provincial impact assessment regimes that have resulted in significant changes to legislation and practice. The Review Board, in an effort to remain at the forefront of impact assessment best practice, has developed a perspectives paper that:

- Describes the Review Board's unique approach to impact assessment and why
- Serves as a basis for improving the effectiveness and efficiency of the Review Board's process
- Support other parts of the integrated land and resource management system to improve practices and to make better informed decisions
- Support the Review Board to lead and participate in collaborative initiatives that could inform the impact assessment processes in other jurisdictions

This paper outlines the "hot topics" or emerging themes in the impact assessment world, why

they matter, and why they are important to the Review Board. Some of the key themes that will be highlighted are:

- Well-being and sustainability assessment
- Collaborative project planning and early engagement
- Climate change
- Cumulative effects and regional strategic environmental assessment

For each theme we outline the current "state of play", existing challenges, best or emerging practices, and desired future outcomes.

This presentation will highlight the findings of the perspectives paper and will initiate future engagement on these emerging themes with interested parties who engage in the Review Board's process.

13 YEARS OF WOLVERINE SNOW TRACK MONITORING AT THE DIAVIK MINE: WHAT HAVE WE LEARNED

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Diavik conducts annual snow tracking surveys for wolverine to test the prediction that the mine would not cause a measurable shift in

wolverine presence in the study area. This prediction has been evaluated primarily through snow track surveys during mid-(December) and late-(March) winter, and by recording direct mine-related incidents and mortalities. Over the 13 years since monitoring began, the program has been adapted from learnings. The first design of snow track monitoring was based on Inuit Qaujimajatuqangit and later adapted to standardize sampling and improve statistical power for detecting change. Another lesson was that there was little value in monitoring during December as the presence of snow tracks was highly variable and limited the ability to detect measurable change. The snow track survey has been completed twice in spring since 2015 to measure track detection rates, which have varied through time. While snow-track monitoring measures relative activity and distribution, it generally corresponds with abundance over time measured from hair snagging. Although wolverine frequent the mine site, improvements in waste management have resulted in fewer mortalities over time, with a long-term average of 0.29 wolverine per year. The long-term trend from snow tracking indicates a slight increased presence of wolverine in the study area. One explanation could be an increase in food availability from range contraction of caribou during the Bathurst decline phase. In conclusion, mortality monitoring indicate a small effect associated with the mine but do not support the mine has adversely affected barren-ground wolverine populations in the NWT.

WORKING WITH GWICH'IN COMMUNITIES TO DEVELOP A MINERALS & MINING STRATEGY

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The October 2018 NWT Economic Symposium, “Northern Strengths, Northern Prosperity“, brought together political leadership of Indigenous governments and organizations, their economic development corporations, and the GNWT. One of the objectives was to more fully inform the dialogue around the NWT’s natural resource base. With the coming closure of NWT’s largest mines, which have been the Territory’s economic powerhouse, and the associated loss of jobs and income, the Premier stressed the need for planning for what comes next.

With the support from GNWT, Gwich’in Tribal Council developed a Mining & Minerals Strategy as a first step to meet this challenge. Indigenizing community outreach was a key to its success. Presenting to the needs and culture of each Gwich’in community was also a consideration. Transparency in the process played a crucial role. The consultancy included one Northerner and others with the appropriate experience and expertise. This approach could serve as a model for other Indigenous land claim groups considering mining and minerals strategy development.

It was unanticipated that the resultant findings would reveal that communities were strongly supportive of mine development and related employment. The possibility of well-paying jobs for Gwich’in participants was welcomed. This was, not unexpectedly, within the context

of manageable environmental impact in certain areas and no impact to sacred or special regions.

The GTC Board approved the recommendations contained in the Strategy. The Mine Training Society held an Introduction to Prospecting course in Inuvik in August – the first time in many years that such training has taken place in the region. It has generated some enthusiasm. Aklavik, the community closest to the largest mineral potential, will be the next venue to offer prospecting training. GNWT has committed to supporting the GTC in moving forward the other recommendations contained in the consultants’ findings.

UPDATE ON RECENT AND PLANNED ACTIVITIES OF THE OFFICE OF THE REGULATOR OF OIL AND GAS OPERATIONS (OROGO)

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Office of the Regulator of Oil and Gas Operations (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 reductions in on-the-land liability as a result of OROGO’s Well Suspension and Abandonment Guidelines, the electronic availability of well history and

seismic program information, new Guidelines under development in 2019-20 and OROGO's Well Watch Program.

RECONSTRUCTION OF THE VOLCANIC AND ORE- FORMING ENVIRONMENT OF THE NEOARCHEAN SUNRISE VMS DEPOSIT, BEAULIEU BELT: IMPLICATIONS FOR VMS FORMATION IN THE SLAVE CRATON

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The Sunrise VMS deposit is located within the Neoproterozoic Beaulieu volcanic belt of the Slave craton, ~110 km northeast of Yellowknife. The belt is comprised of mafic to intermediate volcanic flows with lesser felsic volcanic rocks. The deposit (historic indicated resources of 1.52 Mt at 5.99% Zn, 2.39%Pb, 0.08% Cu, 262 g/t Ag, and 0.67 g/t Au) is a banded polymetallic Zn-Pb-Cu-Ag-Au sulfide lens hosted by rhyolitic rocks, but the age, stratigraphy, and volcanic setting of the deposit remain enigmatic.

Detailed mapping and core-logging of rocks in the Sunrise area indicate a complex stratigraphy comprising numerous lithofacies. The footwall to the deposit consists—from oldest to youngest—of pillow basalt (>200 m),

formerly glassy rhyolite lobes surrounded by hyaloclastite (~100 m), felsic volcanoclastic rocks ranging from tuff breccia to tuff with depositional units between 2–10 m totaling ~100 m, and a massive (~100 m), weakly quartz and plagioclase porphyritic rhyolite dome with brecciated margins. Stratigraphically above the porphyritic rhyolite is a sequence of strongly sericitized and silicified, interbedded felsic tuff to tuff breccia units. These units contain semi-massive, massive, and stringer-style mineralization. The mineralization is dominated by pyrite and sphalerite with lesser amounts of pyrrhotite, galena, arsenopyrite, and chalcopyrite. The felsic tuff to tuff breccia units that host the mineralization are locally overlain by argillite. Where present, the argillite is up to 14 m thick, dark grey to black, finely laminated, and commonly contains pyrite (5–15%), sphalerite (1–2%), and trace amounts of galena, chalcopyrite, and arsenopyrite. The argillite, or the felsic volcanoclastic unit where the argillite is not present, is overlain by pervasively carbonate altered pillowed basaltic-andesite of the hanging wall. Whole rock trace element and Sm–Nd and Lu–Hf isotopic data of the basaltic-andesite units in the footwall exhibit calc-alkaline, arc-like signatures. The mantle source is interpreted to be enriched mantle (E-MORB-type) with a minor degree of subduction zone input (slab metasomatism or sediment subduction).

The rhyolitic rocks of the footwall, totaling over 500 m of stratigraphy, terminate abruptly along strike to the south where the stratigraphy is dominantly intermediate to mafic pillow lavas with subordinate amounts of volcanoclastic rocks. The rhyolite flows and domes indicate a vent proximal environment and the thick sequences of rhyolitic volcanoclastic rocks define a synvolcanic subsidence structure in which they accumulated. This suggests that the deposit, and host volcanoclastic rocks correspond with an area of subsidence, fracturing and the accumulation of permeable

debris on the margin of a rhyolite dome. Synvolcanic faults associated with subsidence would have acted as both magma and hydrothermal fluid pathways adding to the favorable conditions for the formation of a VMS deposit.

**UPDATE ON THE SLAVE
GEOLOGICAL PROVINCE
EXPLORATION
DEVELOPMENT INITIATIVE –
REVITALIZING MINERAL
EXPLORATION AND
FACILITATING SUSTAINABLE
DEVELOPMENT IN A KEY
ECONOMIC REGION**

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In 2018 and 2019, the Northwest Territories Geological Survey (NTGS) implemented the Slave Geological Province Exploration Development Initiative to generate baseline geophysics datasets, bedrock geological mapping products and models, and surficial mapping products to assist the next round of diamond discoveries in the Slave Geologic Province (SGP). The research was focused on parts NTS map sheets 086A, 086H and 076E, with targeted scientific studies 076D and 075M. This project was funded through the Strategic Investments in Northern Economic Development (SINED) of the Canadian Northern Economic Development Agency (CanNor). This work was carried out in conjunction with researchers from Simon Fraser University, Carleton University, the

University of Waterloo, Lakehead University, Mount Royal University, and the University of Saskatchewan. The geophysical surveys and surficial mapping products were produced by Eon Geosciences Inc. and Palmer Environmental Consulting Group Inc. respectively. A case study in the application of hyperspectral drill core scanning to diamond and gold exploration was carried out by Hyperspectral Intelligence Inc. Portions of the field program were made possible by logistical assistance provided by GGL Resources Corp. and Aurora Geosciences Ltd.

Highlights include a new approximately 65,000 line-km 100 m spaced airborne magnetic survey flown over the Point Lake greenstone belt which is prospective, yet underexplored for VMS and gold mineralization, the generation of 10 new 1:50,000 scale surficial mapping products in areas prospective for diamond deposits. Detailed scientific studies were carried out to better understand the effect of glacial and post-glacial processes on the indicator mineral sampling suitability of tills as well as the effective transport distances of indicator minerals in eskers and esker morphology in the SGP. Additionally, a series of 1:10,000 and 1:15,000 scale bedrock mapping initiatives were carried out in areas of elevated resource potential surrounding Newbigging Lake, and Keskarrah Bay on Point Lake designed to increase our understanding the mineralizing processes controlling base metal endowment in the SGP. Preliminary results from the hyperspectral drill core study suggests that it may be possible to use this technology to identify phases in kimberlites and alteration types in gold-bearing systems that are not readily apparent using traditional core logging methodologies.

SKARN MINERAL CHEMISTRY AND IMPLICATIONS FOR HIGH-GRADE TUNGSTEN MINERALIZATION IN THE CANADIAN CORDILLERA

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The Canadian Cordillera is host to numerous ore deposits related with major magmatic events that occurred from Early Jurassic to Eocene-Oligocene. Among these are the Cantung, Mactung and Lened tungsten-bearing skarn deposits, which are spatially associated with the mid-Cretaceous Tungsten plutonic suite of the Tombstone-Tungsten magmatic belt.

The composition of skarn minerals can be used to distinguish between different skarn types, environment of formation, and the redox conditions that prevailed during the skarn formation. For example, the effect of oxygen fugacity during high temperature skarn mineralization produces hedenbergite (Fe²⁺-rich pyroxene) and grossular (Ca-rich garnet) in reduced environments, and diopside (Mg-rich pyroxene) and andradite (Fe³⁺-rich garnet) in oxidized environments. The abundance of sulfide minerals and their sulfidation state also indicate the redox conditions of the skarns; large amounts of pyrrhotite are correlated with reduced skarns, whereas large amounts of pyrite indicate a relatively oxidized skarn. Microprobe analysis undertaken in this study reveal that most of

the skarn minerals at Cantung, Mactung and Lened have compositions indicative of reduced skarns: garnet is grossular-rich with a minor andradite component, and pyroxene is hedenbergite-rich with minor diopside solid solution. The widespread occurrence of pyrrhotite in the three deposits supports a reduced environment during skarn formation. However, nearly pure diopsidic pyroxene also occurs in one of the pyroxene facies of Lened, which is indicative of an oxidized environment. In this specific facies, diopside is associated with Ba-rich feldspar (celsian, ~36wt% Ba) and Ba-F-rich biotite (Ba 11-16 wt%, F ~3wt %). Considering these observations, we suggest that local oxidized conditions may have prevailed at Lened, possibly related to an influx of LILE-rich fluid in the system.

In general, oxidized tungsten skarns are relatively smaller deposits than the reduced skarns. Based on current resource estimates, Cantung (3.8Mt at 0.97% WO₃) and Mactung (33Mt at 0.88%WO₃) are larger and richer deposits than Lened (0.9Mt at 1.0% WO₃), even though they are all associated with the same magmatic event and roughly the same type of host rock. While continued exploration may further refine and modify the deposit metal grades, the mineralogical evidence for oxidized conditions could explain why Lened is less rich. A better constraint of the extent of these oxidized skarns and how they fit in the evolution of the Lened deposit is required to determine their impact on the size and fertility of Lened.

DEFORMATION ALONG THE EASTERN MARGIN OF THE NORTHERN CANADIAN CORDILLERA

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The eastern margin of the Northern Canadian Cordillera is characterized by many earthquakes occurring ~1000 km east of the western North American margin. The ongoing mountain-building processes along the active plate margin in Alaska have been suggested to have caused reactivation of old structures at the far eastern side of the Cordillera. In the Mackenzie Mountains the fold-and thrust belt continues propagating to the east, and dextral strike-slip deformation occurs in the Richardson Mountains farther north.

We investigated the thermal history of rock exposed in the Mackenzie Mountains and the Mackenzie Plain to quantify the timing and amount of cooling and heating related to deformation that caused rock exhumation, erosion and burial. We use (U-Th)/He thermochronology on apatite and zircon grains, which records cooling between 180–40°C. We found three phases of cooling. The two oldest phases, found only in rocks from the Mackenzie Mountains, record the Cordilleran deformation during the Late Cretaceous (100–75 Ma) and Paleocene–Early Eocene (65–40 Ma). These phases of rock exhumation correlate with the deposition, burial and heating of the Devonian and Cretaceous strata collected in the Mackenzie Plain. The thermal history models of our Mackenzie Plain samples suggest burial and heating up to 140°C during Paleocene–Eocene time. The third and youngest phase of cooling

occurred during Oligocene and early Miocene time (33–20 Ma). Thermal history modeling suggests cooling from 120–80°C started 33 Ma and by 20 Ma rock was below 40°C. This young phase of deformation and cooling is recorded in Devonian and Cretaceous strata from the Mackenzie Plain and rock in the eastern Mackenzie Mountains. We recently collected new samples from the Richardson Mountains and preliminary results may suggest a similar Oligocene cooling.

This new finding of post-Cordilleran deformation in the Oligocene time is unexpected and raises questions regarding the driving force. At that time, the western margin of North America was dominated by strike-slip motion and thus unlikely to cause compression towards the east. We therefore suggest that the change in the North American plate motion may have caused deformation. The final opening of the North Atlantic Ocean to the Arctic caused North America to move west and southwest, which may have caused the underthrusting of the ridged craton underneath the weak sediment cover and the fold-and thrust belt.

RECENT GEOTECHNICAL AND SEDIMENTOLOGICAL INVESTIGATIONS BETWEEN INUVIK AND TUKTOYAKTUK, NWT

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The Anderson Plain and Tuktoyaktuk Coastlands, between Inuvik and Tuktoyaktuk in the western Canadian Arctic, are characterized by ice-rich Pleistocene morainal, glaciofluvial, lacustrine and marine sediments. Permafrost is continuous and ranges in thickness from approximately 100 m near Inuvik to over 500 m near Tuktoyaktuk. Knowledge of the geology and Quaternary sedimentology of this region has been developed primarily through investigations between the 1950s and 1980s, often incorporating data from exploration by the oil and gas industry. Additional geotechnical data have been collected in this region since 2012 to support construction and monitoring of the Inuvik to Tuktoyaktuk Highway (ITH). Given their value for future multidisciplinary research and for informing decisions about land use and regional infrastructure development, the objective of this presentation is to introduce and partially

synthesize these recent data.

The data being presented were obtained from geotechnical drilling at 18 alignment and 29 stream crossing sites along the proposed ITH route in 2013, 232 bridge piling installation sites during highway construction, and 16 highway embankment and 16 permafrost Sentinel research sites offset from the ITH investigated shortly before highway completion in 2017. Drilling depths were typically 10 or 20 m. Over 700 additional boreholes were advanced since 2012 near the proposed route to identify aggregate supplies for highway construction, however data from those investigations are not presented here.

Analyses of geotechnical borehole logs and samples obtained by solid stem auger and coring indicate that near-surface materials typically include organics and peat, often in combination with ground ice, while silt, clay and sand generally occur at greater depths. Clay is the dominant substrate type at depths greater than 4 m beneath riparian terrain, with peat at the surface and often an intermediate layer of pure ice, ice-rich silt, or ice-rich clay. Clay and sand characterize the top 20 m of substrate at hilltop sites. Investigations in stream channel banks show surficial material as primarily fluvial sand and gravel, with a general increase in fines in the underlying ground moraine till. Weathered shale bedrock was encountered at two drill sites, and mudstone at six, all less than 50 km north of Inuvik. Geochemical analyses were conducted on sediment samples obtained from the 16 Sentinel sites. Conductivities were mostly between 0 and 4000 $\mu\text{S cm}^{-1}$, and samples were marginally basic with pH generally between 7.5 and 8.0. Dissolved organic carbon concentrations were generally between 0 and 15 mg C L⁻¹, with greater concentrations in some peatlands between approximately 4 and 6 m depths.

Publication of these geochemical, physical, and related ground temperature data by the Northwest Territories Geological Survey and Geological Survey of Canada is intended to support multidisciplinary applied research on the terrestrial and aquatic ecosystems, hydrology, and sensitivity of this permafrost landscape. This resource is also expected to inform regional infrastructure management, and climate change adaptation.

NWT MINERAL EXPLORATION AND MINING OVERVIEW 2019

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In spite of a poor year for sales of rough diamonds globally, diamond mining continues to provide a foundation for the NWT economy. Gahcho Kué mine, which has been operating slightly ahead of plan, announced the discovery of the diamondiferous Wilson kimberlite within the current mine plan area. Consistently high forecasts for zinc demand have encouraged both the rejuvenation of Pine Point by Osisko Metals Inc. and NorZinc Ltd.'s ongoing efforts to bring Prairie Creek into production. Gold prices have been buoyed by safe-haven sentiment after concerns over economic growth, tariffs and trade wars with China. Advanced projects have benefited with an improving investment climate encouraging on-going exploration by Nighthawk Gold Corp. and TerraX Minerals Inc.

However, many smaller projects were suspended as the companies were not able to raise sufficient funds on in the investment

market. This was particularly true for the commodities targeting green energy and battery technologies. Most of the projects focusing on lithium, cobalt and vanadium started the year strongly but were dormant by the summer. A notable exception was the reactivation of Avalon's Nechalacho project with an infusion of resources from Cheetah Resources of Australia.

One of the indicators of exploration activity – claims staked vs. lapsed – continued an upward trend that began in 2017. In 2018, a total of 268 claims covering 184,985 hectares were added and 70 claims covering 58,876 hectares were released. In the first three quarters of 2019, 120 claims covering 45,000 Ha were added but a nearly equivalent area 55,000 Ha in 85 claims and leases were cancelled. There are also 37 active Prospecting Permits this year. New staking included large areas in the Mackenzie Mountains, the additional ground at Pine Point, re-staking of claims in the Lac de Gras region and expansion of claims in the Yellowknife area.

In 2019-2020, the Government of Northwest Territories invested nearly \$1 million in grassroots mineral exploration through the Mining Incentive Program. This funding was dispersed to 19 exploration projects comprising twelve prospectors and seven companies. The Mineral Resources Act has passed the legislature marking the NWT's first-ever stand-alone Act governing mining in the territory.

INSIGHTS FROM BEDROCK MAPPING IN THE MACKENZIE REGION, GEM PROGRAM, 2009 TO 2018

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Up-to-date bedrock geology maps are an important tool for exploration and for assessing geological hazards or geotechnical issues. In the early 2000's, bedrock maps for a large region from the Mackenzie Mountains to the Franklin Mountains and Colville hills were based on reconnaissance work from the late 1960's. These maps incorporated some generalized or informal stratigraphic terminology, and were available only as hardcopy prints or images of the hardcopy versions. To bring these maps up to date with GIS techniques, bedrock mapping activities were conducted by the GSC from 2009 to 2018 as part of the Geo-mapping for Energy and Minerals (GEM) program. During that time, an area covering more than 91,000 km² was updated. By building on historical field observations and incorporating improvements to stratigraphic units from government and academic work over the last 50 years, GEM program maps for the Mackenzie region have revealed new aspects of the geological relationships. These include updating the distribution of economically significant units, resolving problematic correlations, improving stratigraphic resolution and age control, identifying previously unrecognized structures, and adding new constraints to the timing of multiple deformation events.

Revisions to the identification of units are most significant in Tonian strata (Katherine

and Little Dal groups), Ediacaran to lowermost Cambrian strata (upper Windermere Supergroup, Backbone Ranges Formation), lower to middle Cambrian strata, and Cretaceous strata. Updated Cretaceous unit terminology is significant for maps north and east of the Mackenzie Mountains whereas the older units mainly affect the map relationships within the Mackenzie Mountains. Extension of the known distribution of the Coates Lake Group into the Bonnet Plume Lake (NTS 106B) and Ramparts River (NTS 106G) map areas may be of interest to those studying the copper mineralization in these strata. Biostratigraphic work conducted as part of the GEM program has tightened age control, and has aided in unit identification and correlation for intervals in the Ediacaran, Cambrian, Devonian, and Cretaceous. Stratigraphic and thermochronological evidence constrains timing of Laramide contractional deformation within the Mackenzie and Franklin Mountains to mid-Cretaceous to Eocene. The combined stratigraphic refinements have facilitated mapping at a finer resolution, in turn leading to the recognition of additional extensional and contractional structures. Better age controls on units involved in early extensional faulting help constrain the timing of extension to events in latest Tonian, early Cryogenian, late Ediacaran, and early to middle Cambrian.

The recognition of additional faults requires a reassessment of subsurface relationships, connectivity of fluid pathways, and overall shortening across the Foreland Belt of the Cordillera. Based on stratigraphic revisions, correlations, and structural mapping in the northern Mackenzie Mountains, significant revisions to the geological relationships in the central Mackenzie Mountains (NTS map areas 95L, 95M, 105P, and eastern 105I) are likely required, and further study could reveal important aspects of the depositional history and pre-Laramide deformational events.

UPDATE ON THE NEW MINERAL RESOURCES ACT: DEVELOPMENT, ASSENT AND NEXT STEPS

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The Government of the Northwest Territories, led by the Department of Industry, Tourism and Investment (ITI) completed the development and proposal of a new Mineral Resources Act in accordance with strategic policy directives and under the mandate of the 18th Legislative Assembly.

ITI conducted frequent engagements with the Intergovernmental Council Secretariat, Indigenous governments and organizations, industry representatives, other key stakeholders and GNWT departments starting in 2017.

With the use of policy and research work completed, ITI drafted the territory's first stand-alone mineral resources statute which establishes a framework for modernized mineral resources management and administration. In 2019, the proposed Act was introduced in the Legislative Assembly as Bill 34. In the August 2019 session of the Legislative Assembly, Bill 34 (Mineral Resources Act) received 3rd reading.

Though it received assent, the Mineral Resources Act has not yet come into force. This presentation will provide an overview of the legislative initiative through its completion and passing in the Legislative Assembly and next steps including regulations development and implementation.

REGULATORY INITIATIVES

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The Land and Water Boards of the Mackenzie Valley continue to develop policies, guidelines, and standards to enhance the consistency, certainty, and clarity of the permitting and licensing processes.

Initiatives arise in response to emerging challenges, case law, and input from Parties. An overview of initiatives recently completed, as well as details of ongoing and upcoming initiatives will be provided. These initiatives are focused on topics such as: closure cost estimating, the collection of baseline information, water compensation, water license conditions, water source requirements, guides for the permitting and licensing processes, and engagement and consultation.

2019-20 ACTIVITY UPDATE – ENERGY GEOSCIENCES GROUP

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In June 2019, the Northwest Territories Geological Survey (NTGS) Petroleum Geosciences group was renamed Energy Geosciences group. The name change is appropriate as it more accurately reflects the scope of the geoscience research the team is mandated to undertake. This team promotes the development of energy resources in the Northwest Territories (NWT) by evaluating

hydrocarbon and geothermal resource potential, generating regional and thematic geoscience knowledge to underpin successful exploration, and providing scientific advice to inform policy and regulatory decisions concerning these resource areas.

The Energy Geosciences group advanced work on three primary projects during fiscal 2018-19. These include the Shale Basin Evolution Project in the Central Northwest Territories (NWT) (Shale Basin Evolution Project), the Conventional Marketable Gas Resource Mapping Project, and a Geothermal Geoscience Scoping Project. Work continued on these projects into fiscal 2019-2020.

The Shale Basin Evolution Project is a multi-year, multi-disciplinary collaborative study, first initiated in 2014. The study area includes the Mackenzie Plain, Peel Plain, and southeastern Peel Plateau regions of the NWT. The project comprises of three main research components and one data synthesis phase that will culminate in a peer-reviewed publication before March 31, 2021. The research components include a university research collaboration, a regional geological-seismic mapping project, and a regional basin modeling study.

A University research collaboration was initiated in 2016 with Dr. Murray Gingras of the University of Alberta (U of A) and three graduate students. The objective of the U of A research project is to assess the reservoir quality of the Upper Devonian Shales of the Central Mackenzie Valley, Northwest Territories using sedimentology, ichnologic, and geochemical parameters. These data and various other parameters will also be used to establish a high-resolution sequence stratigraphic framework and assess paleoredox conditions and organic matter type and distribution in the Horn River Group. The U of A 2019-20 project deliverables includes

project documentation, multiple peer-reviewed publications, and some additional geochemical research.

Fieldwork was conducted in July 2019, to support the Shale Basin Evolution Project and to scope several outcrops identified for future Imperial Formation related research.

A regional geological-seismic mapping project was recently undertaken to create good quality subsurface formation isopach and structure maps for input into the basin modeling study. Initial basin modeling results are targeted for 2020.

The Conventional Gas Resource Mapping Project was completed in fiscal 2019-20 and is currently in the Open Report publication process. The soon available map will show the distribution of discovered natural gas resource volumes in the NWT, as reported by the National Energy Board in 2014, with respect to communities, existing pipelines, and road infrastructure. Shapefiles and metadata for the ArcGIS project will be published with the Open Report.

Lastly, a reservoir characterization study of the Nahanni Formation carbonate was commenced in the Fort Liard area of the NWT. The purpose of this study is to assess reservoir quality, continuity, and reservoir risk factors associated with the Nahanni Formation as a potential geothermal resource reservoir. This study will be completed by March 31, 2020.

EXTREMELY LOW FREQUENCY (ELF) PASSIVE EM SURVEY FOR CONDUCTIVITY MAPPING OVER KNOWN SULPHIDE DEPOSITS IN BATHURST, NB

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Volcanogenic massive sulphide (VMS) deposits have been mined in northern New Brunswick since their initial discovery in the 1950's. Geological and geophysical methods were used to find 46 known deposits including the famous Brunswick 6 mine. Past exploration efforts during the last 2 decades (mostly through the EXTECH2 and TGI3 programs) have resulted in a large database of high-resolution airborne and ground geophysical data, consisting mostly of magnetic, gravity and conventional DC IP and resistivity surveys. Although this database did not succeed in reaching early levels of success in Bathurst, it provides us with a collection of geophysical signatures over known deposits that can be used to test new instrumentation. The pyrrhotite-rich sulphide deposits in the area have strong conductivity contrasts with the host rock and can be identified using electromagnetic (EM) survey methods.

Recently, Aurora Geosciences Ltd. has been using an extremely low frequency (ELF) passive EM system to map conductivity structures. A similar airborne system, ZTEM (developed by Geotech), has already proven its usefulness mapping porphyry deposits around

the world. The ELF system measures horizontal and vertical components of the Earth's geomagnetic field. Tilt angle, otherwise known as the tipper, is comprised of these components and recorded for eight frequencies between 11 and 1440 Hz. While dependent on the conductivity in the top-most layers (skin depth), the ELF system can image up to 2 km depth. A deep penetrating EM method, such as the ELF, is a perfect use case for the overburden covered deposits of northern New Brunswick.

Several transects were collected using the ELF system over known VMS deposits at Key Anacon Mine. Using the currently mapped deposits from Osisko Base Metals, three survey locations were selected; one over the 'Titan Zone' & two over the 'Main Zone'. This presentation focuses on the preliminary results derived from the surveys. Total divergence (DT), total phase rotation (TPR), and tipper vectors for both in-phase and quadrature components were computed. These data are compared with known geology & legacy datasets to associate ELF data with real world structures and geophysical signatures typical of VMS deposits.

NWT THERMOKARST MAPPING PROJECT

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Permafrost thaw is a primary cause of climate-driven landscape change in the north and has a major effect on ecosystems and infrastructure. Understanding the distribution of thaw-sensitive terrain is critical to predict the future state of the environment and water resources in the Northwest Territories (NWT), and for planning community and infrastructure adaptation to climate change. Although several local-scale mapping products describing the nature, intensity, and distribution of thermokarst processes and permafrost landforms are currently available, there are no NWT wide, observationally-based maps that depict the distribution of landforms indicative of permafrost thaw or sensitive terrain. This collaborative project has drawn on experts from across Canada, forming a northern-driven partnership aimed to develop a method for identifying thermokarst landforms and to map sensitive permafrost terrain to generate NWT-wide thermokarst and permafrost feature inventory maps. Through an iterative process, satellite imagery, combined with a 7.5 x 7.5 km gridded cell system is being used to inventory the location and relative density of

features throughout the NWT and transboundary watershed areas using remote sensing and GIS software. These features are grouped into the following themes:

- A) Thawing slopes and mass-wasting;
- B) Hydrological features;
- C) Organic terrain; and
- D) Periglacial landforms.

A QA/QC process integrating local-scale mapping products and expertise of academic and community partners will be applied to validate the empirically-based maps. Preliminary efforts to test the mapping methodology are focused on areas around the 33 NWT communities. The second component of this project will involve training northern students and project partners to use this method to create inventory maps for the entire NWT and the adjacent Provincial/Territorial transboundary watershed areas. Outputs will provide information relevant to all NWT regions, inform and validate modeling efforts, and support community climate change adaptation.

TILL PROVENANCE ACROSS GLACIAL LANDSCAPES OF THE LAURENTIDE ICE SHEET IN CENTRAL NUNAVUT AND EASTERN NORTHWEST TERRITORIES

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Our research documents glacial dispersal within the interior region of the Keewatin Sector of the Laurentide Ice Sheet, mainland Northwest Territories and Nunavut, to better understand till provenance and refine regional glacial transport models to improve surface exploration methods in the Rae and Hearne provinces of the Canadian Shield. The objectives of this study are to:

1) characterize the regional till composition (provenance) across major geological and glaciological features; and

2) evaluate glacial transport in areas of complex ice flow dynamics and changing basal ice thermal regimes.

Selected ~100-km long transects incorporate previous and new surface till composition datasets (clast lithology, texture and matrix geochemistry/mineralogy) from samples collected at a regional scale (~10-km spacing)

across various glacial terrains such as paleo-ice stream corridors, major moraine systems, relict landscapes and ice divides. Specifically, the study includes transects crossing former ice front positions marked by the MacAlpine and the Chantrey moraines, the onset zone, trunk and terminus of major ice streams (e.g., Dubawnt Lake, Maguse Lake and Rae Isthmus ice streams), the Keewatin Ice Divide, relict cold- to intermediate-based terrains, and areas impacted by patchy sustained normal vs. fast flowing ice (i.e., sticky spots). The distribution of distinct bedrock lithologies (e.g., Dubawnt Supergroup) as source indicators combined with multivariate analysis of the geochemical composition of the till matrix will be used to evaluate the distal, proximal and possibly palimpsest and/or inherited components of glacial transport history, and document its relation with the type of glacial landscape. Overall, these results will have implications for future surface mineral exploration at a regional scale in northern Canada. This work is part of the Rae Synthesis of Glacial History and Dynamics Activity under the GEM-2 Program, and is a collaboration between the Geological Survey of Canada, the Northwest Territories Geological Survey and the Canada-Nunavut Geoscience Office.

MINERAL ADMINISTRATION AND REGISTRY SYSTEM (MAARS)

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The Department of Industry, Tourism and Investment was notionally approved for capital funding to undertake a modernization of their

mineral administration system, following the completion of the Mineral Resources Act (MRA). The project, dubbed MAARS, will establish a modernized system for mineral interest management and administration.

When the new Mineral Resources Act comes into force it will require a significant modernization of the current NWT mineral resources management technology.

The Mining Recorders' Office (MRO) manages most mineral resources administration and implementation of the regulatory requirements. The MRO's current application is not capable of delivering the scope and functions demanded by the new MRA.

The new MRA sets out requirements for mineral prospecting, exploration, development and production in the Northwest Territories. It governs the issuance of interests in minerals, and provides tools for incentivizing development. Furthermore, the GNWT must notify Indigenous Governments and organizations of applications to record claims.

With the development of the MRA there are substantial new requirements for electronic business processes in order to deploy functions such as these efficiently and effectively.

BURING SHALES AND EXTREME ACIDITY - TOXIC STEW IN THE SMOKING HILLS

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The Smoking Hills, east side of Cape Bathurst, Canadian Arctic, are characterised by emissions of smoke composed of water vapour and hot sulphuric acid gases from vent holes (termed bocannes) that are surrounded by variable, but often brightly coloured, mineral deposits. The burning has been shown to be related to combustion of organic matter and is associated with oxidation of disseminated pyrite within the shales. Extinct sites that are no longer venting gas are characterised by vividly coloured brick red to yellow deposits of thermally altered shale known as clinker deposits. Auto combustion of the Smoking Hills Formation is not restricted to sea cliffs of Franklin Bay as thought by earlier workers. We observed that both bocannes and clinker sites occur over a wide area of Cape Bathurst, between Franklin Bay and the Anderson River, that occur in clear association with outcrops of the bituminous Smoking Hills Formation. Actively burning sites all occurred in areas with evidence of recent slumping that has exposed fresh surfaces of the bituminous shale, either by sea or stream erosion of outcrops. Also, bocannes form not only directly below the failure faces, but within debris flow lobes extending well down-slope of the initial failure.

Previous work in this area noted ponds with pH values as low as 3. Workers had suggested that ponds were acidified in a process similar to modern anthropogenic acid rain acidification of lakes, whereby clouds of acid gas from bocannes

blown inland acidify ponds in the downwind direction. This previous work though did not examine the ponds relative to the bedrock geology. We show that acid ponds are restricted to outcrop of the Smoking Hills Formation. Some ponds show extreme acidity with pH as low as negative 1.44 (-1.44). In contrast, ponds that are being actively fumigated by burning shales, but lie on the Mason Formation, or glacial materials, are near neutral pH, showing that pH is moderated by the strong buffering capacity of the underlying bedrock. We hypothesize that the occurrence of acid ponds is related to a process more similar to natural acid mine drainage rather than acid rain. We tested this through lab experiments, whereby samples of the Smoking Hills Formation are shown to acidify waters within hours of exposure. Along with low pH, these waters have extremely high trace metal content, creating some of the most toxic naturally occurring waters known.

GROUND SUBSIDENCE AND HEAVE OVER PERMAFROST: HOURLY TIME SERIES REVEAL INTER-ANNUAL, SEASONAL AND SHORTER-TERM MOVEMENT CAUSED BY FREEZING, THAWING AND WATER MOVEMENT

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Heave and subsidence of the ground surface can offer insight into processes of heat and mass transfer in freezing and thawing soils.

Additionally, subsidence is an important metric for monitoring and understanding the transformation of permafrost landscapes under climate change. Corresponding ground observations, however, are sparse and episodic. A simple tilt-arm apparatus with logging inclinometer has been developed to measure heave and subsidence of the ground surface with hourly resolution and millimetre-accuracy. This presentation reports data from the first two winters and the first full summer, measured at three sites with contrasting organic, and frost-susceptible soils in warm permafrost. The patterns of surface movement differ significantly between sites and from a prediction based on the Stefan equation and observed ground temperature. The data is rich in features of heave and subsidence that are several days to several weeks long and that may help elucidate processes in the ground. For example, late-winter heave followed by thawing and subsidence, as reported in earlier literature and hypothesised to be caused by infiltration and refreezing of water into permeable frozen ground, has been detected. An early-winter peak in heave, followed by brief subsidence, is discernible in a previous publication but so far has not been interpreted. An effect of precipitation on changes in surface elevation can be inferred with confidence. These results highlight the potential of ground-based observation of subsidence and heave as an enabler of progress in process understanding, modeling and interpretation of remotely sensed data.

YELLOWKNIVES DENE FIRST NATIONS AND DET'ON CHO CORPORATION AS THEIR ECONOMIC ARM – HOW THEY COLLABORATE EFFECTIVELY

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Resource companies often struggle on how to engage with impacted First Nations and in particular getting alignment between the First Nation and their perspective development corporations. Over the past 2 years Yellowknives Dene First Nations (YKDFN) and its development corporation Det'on Cho Corporation (DCC) have made a considerable effort to align between the two entities. The talk will be provided by the CEO of YKDFN and the CEO of DCC and will review where the YKDFN and DCC relationship started, how it has evolved, what steps have been taken to strengthen the relationship and enhance transparency and communication. Lastly the speakers will provide recommendations on how to approach YKDFN / DCC and other Indigenous groups with potential opportunities in the resource sector.

LUPIN WINTER ACCESS: PERMITTING ACCESS TO AN EXISTING TRANSBOUNDARY WINTER ROAD CORRIDOR THROUGH NORTHWEST TERRITORIES AND NUNAVUT

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In order to support ongoing reclamation and final closure activities at an existing mine site in Nunavut, the contractor for the remediation works, Nahanni Construction Ltd., undertook permitting to use a 200 km portion of the existing Tibbitt to Contwoyto Winter Road corridor, from the Ekati Mine turnoff on Lac de Gras to the mine on Contwoyto Lake, to haul equipment and supplies from Yellowknife. This presentation examines the parallel processes undertaken simultaneously in Nunavut and Northwest Territories to obtain access to the winter road corridor, including various applications for surface land access (MVLWB, CIRNAC, KIA) and related authorizations, and highlights both the similarities and differences in permitting a contiguous land use across multiple jurisdictions. Lessons learned from this activity are considered especially valuable in light of the recent funding announcements in support of transportation corridor development through the same transboundary area, being the Slave Geologic Province Corridor project in NWT and the Grays Bay Road and Port Project in Nunavut.

POLYMETALLIC U-NI-CO-AS-AG-BI VEIN DEPOSITS IN THE NORTHWEST TERRITORIES, CANADA: THE PRODUCT OF HEATING AND OXIDATION OF MARINE EVAPORITE BRINES AND METAL-ENRICHED HYDROCARBONS WITHIN CRYSTALLINE BASEMENT

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Polymetallic, U-bearing “five-element”-type vein systems in the NWT show contrasting grade and tonnage characteristics from one deposit district to another. The results here conclude a 3-year study comparing sub-economic examples in the Great Slave Lake area that are hosted in Archean (Slave craton) and Paleoproterozoic rocks (East Arm basin) and in the Great Bear Lake area that are hosted in Paleoproterozoic rocks (Great Bear magmatic zone), including an historically world-class deposit at Port Radium (Eldorado: ~13 Moz Ag; 6000 t U₃O₈). Integration of a variety of microanalytical methods has focused on: (i) characterizing processes responsible for ore metal precipitation; (ii) the source of metals and fluids, and (iii) the timing of vein formation.

In basement (host) rocks, early, pre-mineralization fluids were heated basement brines (minimum ~150-200 °C; rich in Ca-Na-Sr-Ba; ~20-30 wt% CaCl₂ eq.). Mineralization formed when immiscible hydrocarbons and marine evaporite brines (rich in Ca-Na-Mg-Pb-Zn; 20-35 wt% CaCl₂ eq.; very low Cl/Br ratio) were introduced along basement faults. A large shift in brine $\delta^{18}\text{O}_{\text{VSMOW}}$ by +10 ‰ suggests that basement faults were efficiently flushed by these sedimentary basin-derived fluids at the time of mineralization. Both basement- and sedimentary basin-derived brines were poor in ore metals, containing only sub- to low-ppm concentrations. In contrast, immiscible hydrocarbons, now entrapped in fluid inclusions, were metal-rich, containing 100s of ppm U-Ni-Co-Bi-Ag-Sb-As-Mo-Cu. Integration of all data types shows that metal precipitation was triggered by mixing of heated, oxidizing basement brine (metal-poor) with evaporated seawater and metal-rich oil at $P < 1$ kbar and ~200 °C.

At the Eldorado deposit, a revised age for arsenide-stage mineralization is constrained to 1442 ± 36 Ma by U-Pb (SHRIMP) geochronology of coeval hydrothermal xenotime. During that time, the Dismal Lakes Group of the Hornby Bay Basin was deposited (~1438 ± 8 Ma); the presence of both evaporites and black shales in this succession implicate its role in the supply of evaporitic brines, hydrocarbons, and metals to polymetallic vein systems. More broadly, brines and metal-rich hydrocarbons were likely sourced from former overlying intracratonic basins (e.g., Hornby Bay, Thelon, Athabasca) that covered a vast area at the time of vein formation.

As an exploration tool, fluid inclusion chemistry allows the discrimination of small, sub-economic deposits that formed in deep basement rocks, (farther below overlying metal sources) from shallower, much larger economic deposits that formed immediately below mature

basin sequences. High grade polymetallic “five-element” vein systems can be linked to the protracted metallogenic evolution of previously overlying intracratonic sedimentary basins, and the metal endowment of these vein systems may be entirely unrelated to granitic magmatism in the Great Bear magmatic zone, aside from these contributing heat to drive fluid circulation.

CLASSIFICATION OF HYDROTHERMAL CU-PB- ZN- AG MINERALIZATION IN THE NONACHO BASIN, NORTHWEST TERRITORIES

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Field observations of polymetallic vein occurrences (Ag and base metal - Cu, Pb, Zn) mineralization in the Nonacho Basin (Churchill Province) suggest that the mineralization style at Crest and Salkeld Lake are late-stage with respect to other (e.g., U, Fe) styles in the basin. Host rock lithologies consist of intensely folded and faulted metasedimentary rocks (clastic) and biotite and granitic gneiss with lesser felsic-intermediate intrusions. Stockwork- and shear-style mineralization occur along, and cross-cut, metaigneous-metasedimentary contacts. A variety of alteration styles affect the host rocks but predate mineralization including i) early

quartz-feldspar ± magnetite veins, ii) epidote ± hematite as pervasive replacement and veins, iii) black chlorite that pseudomorphs biotite in gneiss, and iv) quartz stockwork ± muscovite, carbonate. These alteration assemblages are observed throughout the basin.

An initial goal is to provide a deposit classification (i.e., IOCG, porphyry, skarn, etc.). Petrographic analysis of samples shows at least three different mineralization assemblages comprising stockwork- or fracture-hosted styles. These include: (i) disseminated and fracture-hosted chalcopyrite within metasedimentary and gneissic host rocks; (ii) massive quartz-(carbonate) veins containing bornite-chalcopyrite vug infill; (iii) sulfide-quartz breccias containing angular to sub-rounded clasts of earlier quartz vein material surrounded in massive (in order of abundance from highest to lowest) galena-sphalerite (cadmium-rich)-bornite-chalcopyrite. Optical and scanning electron microscopy show that all sulfides are texturally late-stage relative to quartz-carbonate, and that where bornite is present, it replaces chalcopyrite. All mineralization styles are associated with early silicification-sericitization manifesting as a bleached appearance in the country rocks in vein halos, and a later carbonate-barite-fluorite alteration assemblage.

Preliminary observations on fluid inclusions show that quartz fragments host abundant secondary inclusion trails containing mixed liquid-vapour inclusions containing a low density vapour phase, consistent with either boiling and/or a very shallow level of formation.

The style of mineralization (quartz-carbonate-sulfide vein and breccia), composition of the mineralized assemblage (galena, sphalerite, chalcopyrite, bornite), and associated alteration styles (silicification, sericitization followed by carbonate, barite, fluorite) is reminiscent of both high and low temperature deposit styles.

Possible comparable mineral deposit styles include: (i) base metal skarns (e.g., Whitehorse Copper Belt, YT; Gaspé, QC); (ii) manto-type carbonate replacement deposits occurring peripherally to known or suspected porphyry deposits (e.g., Butte and Leadville, USA; Prairie Creek, NWT) (iii) clastic metasediment vein-hosted base metal deposits (Keno Hill, YT; Coeur d'Alène, USA). Future work will comprehensively evaluate these mineralization styles as possible analogues for the Nonacho Basin occurrences and establish their relationship, if any, to earlier mineralization styles and potentially causative intrusions.

POLYPHASE CORDILLERAN DEFORMATION IN THE SELWYN FOLD BELT, NAHANNI REGION, NWT AND YUKON

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The Selwyn fold belt (SFB) in the eastern Yukon and southwest NWT is a zone of NE-SW oriented crustal shortening that developed in clastic sequences of the Neoproterozoic to Silurian Selwyn basin and subsequent Devonian to Triassic back-arc basins. The SFB developed in the foreland of the Cordilleran orogeny and is located between the Cordilleran metamorphic hinterland of the Yukon-Tanana terrane to its SW and the classic fold and thrust belt in carbonate

dominated shelf sediments of the Mackenzie platform to the NE. The SFB is generally described as comprising spaced thrusts that separate panels of regionally extensive, closed to tight, upright folding and associated axial planar foliation development. Rocks of the SFB in the Nahanni region of southwest NWT and eastern Yukon preserve multiple generations of folding and overprinting penetrative foliation development indicating that the kinematic evolution of the SFB was, at least locally, quite complex. This study presents results of a detailed structural analysis of penetrative deformation of the southern SFB in the Nahanni region.

Structural data collected along SW-NE sections across the SFB from the NWT and into the Yukon. The northern section, from Howard's Pass to Summit Lake, traverses the Selwyn Basin and the overlying Earn Group. The southern section, from the Fork Creek range to Little Owls Lake, traverses the Hyland Group. North of Little Owls Lake, a regionally consistent, moderately to steeply dipping, penetrative foliation is observed in most outcrops, and it is axial planar to folding at all scales. At Little Owls Lake, three fabrics are consistently observed: a moderately steep dipping crenulation foliation (S_1) axial planar to NW-plunging and NW-dipping inclined folds; an overprinting subvertical crenulation cleavage (S_2) axial planar to upright folds (F_2); and a late northeast-striking, steep crenulation cleavage (S_3) with no associated mesoscopic or macroscopic folding (S_3). Based on similar attitudes and fold geometries, the S_2 fabric observed at Little Owls is correlated with the regional foliation observed north of Little Owls along both sections. Chlorite-zone metamorphism extends across both sections, and both grade into biotite-zone metamorphism along the Fork Creek range. At the southern end of the Fork Creek range syn-kinematic cordierite, andalusite, and rare staurolite porphyroblasts are developed in coarse-grained

biotite-quartz schists that preserve additional foliation generations not observed elsewhere. This zone of higher metamorphic grade is spatially associated with the Nahanni pegmatite suite, and is likely a function of heat conducted from a source intrusion at depth.

The geometry of the penetrative foliations and the overall fold continuity indicate that there is no geometric requirement for significant displacement along thrust faults within the study area. Fewer deformation events are recorded along the Summit Lake section than in the Little Owls Lake or the southern Fork Range areas. This may indicate that deformation propagated from south to north (present coordinates) along the section, and/or from deeper to shallower stratigraphic levels in the crust.

MINING MATTERS: RAISING EARTH SCIENCE AND MINERAL RESOURCES AWARENESS THROUGH PARTNERSHIPS

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Mining Matters is a charitable organization whose mission is to educate young people to develop knowledge and awareness of Earth sciences, the minerals industry, and their roles in society. The organization provides current information about rocks, minerals, metals, mining and the diverse career opportunities available in the minerals industry. Mining Matters offers exceptional educational resources that meet provincial curriculum expectations, created by educators and Earth

science experts. Since its founding in 1994, Mining Matters has reached an estimated 750,000 teachers, students and members of the public.

Mining Matters has been working in partnership with the Government of the Northwest Territories, Department of Industry, Tourism and Investment to deliver Earth science and mineral resources content in numerous communities, including Tulita, Norman Wells, Coville Lake, Deline, Fort Good Hope, Yellowknife (including teachers from Whatì, Gamètì and Wekweètì), Dettah, Ndilo, Behchokò and Hay River, developed with sensitivity to the importance Indigenous communities play in resources stewardship, management and development.

Through our Mining Rocks Earth Science Program, we facilitate engaging hands-on learning activities for young people. Students match everyday items to the minerals from which they are made, learn about the mineral resource development cycle, test mineral properties, engineer a headframe, design a water filtration system and create items with metals.

Mining Matters raises awareness about the wide range of career opportunities available in the minerals industry through interaction with professionals and showcasing career resources from MiningNorthWorks.com. Students from Yellowknife and Behchokò participated in field trips to Ranney Hill Geological Interpretive Trail, led by career role models from TerraX Minerals Inc. There, students discovered the geology of the area and learned how to examine rocks using geological equipment.

Mining Matters has participated in the Yellowknife Geoscience Forum and the Northwest Territories Teachers' Association Conference. Our Teacher Training Workshop provided educators with resources including

lesson plans, rock and mineral samples, equipment and teaching strategies that met curriculum connections in Earth science and mineral resources education.

The Geoscience Aware Challenge was created for the Girl Guides of Canada, Manitoba Chapter, through a partnership among Mining Matters, Girl Guides of Manitoba, the Government of Manitoba, and the Canadian Geoscience Education Network. The Challenge activity book explores a series of Geoscience Literacy Principles through more than 30 hands-on learning activities. Guides, ranging from Sparks through to Rangers, earn their Challenge crest by completing a requisite number of activities, depending on Guide level, associated with each of the stated Geoscience Literacy Principles. Future plans include partnering with NWT Girl Guides to expand the Geoscience Aware Challenge into the Territory. This would involve creating local and regional content to reflect the geology of the Territory and the interests of the local and regional Guide communities.

BAFFINLAND'S MARY RIVER HIGH GRADE IRON DEPOSITS, NORTH BAFFIN ISLAND, NUNAVUT

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The Mary River area, on northern Baffin Island, is a major high grade iron ore camp with several variably delineated high grade magnetite - hematite / martite deposits, the largest in excess of 600 mt of 66% Fe. These

deposits are hosted within a prominent Algoma-type banded iron formation (BIF), a key member of a BIF - volcanic - wacke assemblage, which comprises the Neoproterozoic Mary River Group. The sequence is preserved within fold belts of variable scale, across the northwestern part of the Rae Domain, Churchill Province - an area informally termed the "Mary River District". Within the fold belts, the iron formation has been structurally thickened locally to a significant extent. High grade iron deposits occur concentrated at the closure of major folds and along nearby fold limbs. Exploration across the Mary River District, has focused on evaluation of high grade iron potential in well preserved portions of the widely distributed fold belts. Several new zones of high grade iron mineralization were identified during the 2019 exploration field program.

Mary River direct shipping ores (DSO) are characterized by exceptionally high Fe grades, but are also low in deleterious elements, have attractive physical and metallurgical properties, and are hard - the latter resulting in a high lump ore ratio. The ore requires no processing, only crushing and screening. The main deposits, scheduled for initial mining, comprise Deposit 1 with 418 mt grading 66.3% Fe (measured + indicated) and 213 mt grading 66.9% Fe (inferred) and Deposits 2+3 with 23 mt grading 65% Fe (M + I) and 336 mt grading 65.9% Fe (inferred). Ongoing drill programs at Deposits 1 through 3 are focused on further delineation of the main mineralized zones and testing of exploration targets in the immediate vicinity. The high grade iron ores are being consumed mainly by the European steel industry and are marketed as Lump (DSP) and Fine (SSF) products. Full scale mining of Deposit 1 was initiated in 2015. During 2018, ~5.1 mt of high grade ore was shipped from Milne Port - including 3.28 mt of DSP (@67.7% Fe) and 1.82 mt of SSF (@66.8% Fe). Production in 2019 is anticipated to be ~6 mt of DSO. Plans are

moving forward with construction of a railway and expansion of port facilities to support future increased high grade iron ore production.

THE FURY AND HECLA GEOSCIENCE PROJECT: OVERVIEW OF THE 2019 THEMATIC RESEARCH ON MELVILLE PENINSULA, QIKIQTAALUK REGION OF NUNAVUT

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The Fury and Hecla Geoscience Project is a multi-disciplinary initiative that involves regional mapping and thematic research in the areas of Baffin Island and Melville Peninsula surrounding the Fury and Hecla Strait, in the Qikiqtaaluk Region of Nunavut. The project is led by the Canada-Nunavut Geoscience Office, and thematic research is performed through collaborations with Laurentian University, McGill University, and the Université du Québec à Montréal. In the year of 2018, a first field season focussed on bedrock exposures located in Baffin Island. In the year of 2019, field activities continued in Baffin Island, but the major focus of thematic work shifted to mapping and resolving the stratigraphy of the Fury and Hecla Group on Melville Peninsula and islands within the Fury and Hecla Strait. Thematic work also includes laboratory analyses on sample suites collected in the

previous year.

We provide an overview of thematic work on the Fury and Hecla Group, a thick succession of sedimentary rocks of inferred Mesoproterozoic age that broadly correlate to other successions of the Bylot basinal system in northeastern Nunavut and northwestern Greenland. The Fury and Hecla Group is comprised of predominantly shallow-marine rocks of the sandstone-dominated Nyeboe and Sikosak Bay formations, the shale-rich Agu Bay Formation, the sandstone-dominated Whyte Inlet Formation, and the sandy to muddy Autridge Formation. Thematic research on the sandstone-dominated units is aimed at resolving their sedimentary facies, stratigraphy, depositional architecture, and provenance. Such research was performed on exceptional exposures laterally and vertically continuous over kilometres, and a suite of samples analyzed through sensitive high-resolution ion microprobe to reconstruct the age structure of detrital zircon. Organic-rich shale units of the Agu Bay and Autridge formations were targeted for redox-sensitive geochemical, paleobiological, and Re-Os analyses to expand on the rich geobiological archive represented by the Bylot basins, provide new geochronological constraints and the Fury and Hecla Group, and establish more robust correlations with other Bylot basins.

MICROBIAL COMMUNITY FINGERPRINTING AS A TOOL FOR DIRECT DETECTION OF BURIED KIMBERLITES

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Mineral exploration in northern latitudes is challenging in that undiscovered deposits are likely buried beneath significant glacial overburden. The development of innovative exploration strategies and robust techniques to see through cover is imperative to future discovery success.

Microbial communities are sensitive to subtle environmental fluctuations, reflecting these changes on very short timescales. Shifts in microbial community profiles, induced by chemical differences related to geology, are detectable in the surficial environment, and can be used to vector toward discrete geological features. The modernization of genetic sequencing and big-data evaluation allows for efficient and cost-effective microbial characterization of soil profiles, with the potential to see through glacial cover.

Results to date have demonstrated the viability of microbial fingerprinting to directly identify the surface projection of kimberlites in addition to entrained geochemical signatures in till. Soils above two kimberlites in the Northwest Territories, have undergone microbial community profiling. These community-genome derived datasets have been integrated with chemistry, mineralogy, surface geology, vegetation type and other environmental variables including Eh and pH. Analyses show significant microbial community shifts, correlated with the presence of kimberlites, with a distinct community response at the species level directly over known deposits. Diversity of soil bacteria is also depressed in the same regions of the microbial community response. The relationship between microbial profiles and buried kimberlites has led to the application of microbial fingerprinting as a method to accurately delineate potential ore deposits in covered terrain.

The integration of microbial community information with soil chemistry and landscape development coupled with geology and geophysics significantly improves the drill / no-drill decision process and has proven to be far more accurate than traditional surficial exploration methods. There is high potential for application as a field-based technique as microbial databases for kimberlites in northern regions are refined, and as sequencing technology is progressively developed into portable platforms.

SPATIOTEMPORAL PATTERNS OF MINING-ASSOCIATED METALS IN SUB-ARCTIC LAKE SEDIMENTS

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Gold found on the shores of Great Slave Lake in 1935 has led to a legacy of pollution in Canada's North. Mining operations at two major gold mines, Giant and Con, released a fine, toxic dust into the atmosphere during the extraction process – arsenic trioxide (As_2O_3). A lack of emission controls resulted in the release of over 20,000 tonnes of As_2O_3 into the atmosphere which dispersed onto the landscape surrounding Yellowknife. Most of it was discharged from Giant Mine in the 1950s and has potentially created repositories in the many lakes, rivers, and soils. In the absence of long-term environmental monitoring prior to and during resource development, identifying the

extent of pollution is challenging but important for assessing risks to ecosystem health. Measurements of arsenic concentrations in lakewater and surficial sediment surveys have supported conclusions that no potential ecosystem health effects exist beyond a 30-km radius. However, paleolimnological studies at distances well beyond 100-km have identified elevated arsenic concentrations aligning with the timing of peak emissions. Findings suggest that the size of the area that received pollution from Giant and Con Mines remains poorly understood and further research is needed to fully characterize the emissions footprint. To address this need, spatial and temporal patterns of metal deposition are being reconstructed from the analyses of lake sediment cores along an 80-km transect following the prevailing wind direction (NW). Preliminary results are consistent with other previous paleolimnological studies and instill confidence in the use of sediment cores as natural archives. Arsenic concentrations are well above the CCME Probable Effects Level of 17 mg/g in lake sediment records obtained as much as 80 km from the mines during peak emissions. Distinct differences in metal deposition have been observed along the transect. Substantial increases in arsenic and antimony concentrations towards the sediment surface occur at lakes from 10 to 40 km (near-field). In contrast, lakes located from 50 to 80 km (far-field) have well-preserved Giant and Con mine signals, with arsenic and antimony concentrations returning to approximately pre-industrial levels towards the surface. Stratigraphic variations in arsenic concentrations and arsenic inventories, which represent the total amount of excess arsenic in lake sediment relative to pre-industrial background concentrations, identify pollution has travelled farther than previously believed. Perhaps most interestingly, concentrations do not entirely decrease with increasing distance from the mines. Differences in mining-

associated metal loading and profile preservation may be due to diagenetic processes, a continued supply of metals from legacy stores in the surrounding catchment, or differences in bedrock geology between lakes. Ongoing analyses including radiometric dating will aid in determining the relative roles of sedimentation rates, natural processes such as forest fires surrounding individual catchments, and how varying landcover types may influence sediment metal profiles.

TUNGSTEN MOBILITY IN TAILINGS WATERS, CANTUNG MINE, NORTHWEST TERRITORIES

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The Cantung Mine in the western Northwest Territories was a leading global producer of tungsten (W) intermittently from 1962 to 2015, and is currently owned by Crown Indigenous Relations and Northern Affairs Canada. The mine hosts five tailings ponds (~6.5 Mt total), as well as ~172,000 t of tailings that were deposited directly on the Flat River floodplain during its first three years of production. The tailings vary in terms of their mineralogy and degree of oxidation, which provides an excellent setting to study factors controlling W mobility in the surface environment. As concerns about the potential toxicity of W have only recently emerged, there is a lack of literature regarding its transport and sequestration in the environment. In particular, few studies have

addressed W mobility in mine tailings, which could act as a point source of metal leaching. Furthermore, interest in reprocessing the Cantung tailings to recover tungsten from its primary mineral, scheelite (CaWO_4), warrants the identification of phases that may be secondary hosts.

In July 2018, nine surface water samples, nine tailings pore-water samples, and thirteen tailings samples were collected from the Cantung Mine's tailings. The water parameters temperature, conductivity, pH, and oxidation-reduction potential were measured in the field using portable metres, and water samples were filtered with a $0.45\ \mu\text{m}$ syringe filter. Unfiltered water aliquots were collected in tandem to compare between dissolved and particulate element concentrations. Water samples have been analyzed by high resolution inductively coupled mass spectrometry, and for the anions SO_4^{2-} , NO_3^{2-} , Cl^- , F^- , and PO_4^{2-} by ion chromatography. Tailings samples have been examined by scanning electron microscopy, as well as synchrotron-based μX -ray diffraction (μXRD) and μX -ray fluorescence (μXRF) to identify secondary hosts of W.

Samples from Tailings Pond 3 (TP3) are variably altered, and have abundant primary calcite, dolomite, and pyrrhotite, with neutral porewater (pH = 7.05). The Flat River Tailings (FRT) have porewaters with pH between 2.20 – 7.61, and virtually all carbonate and sulfide minerals have dissolved and been replaced by secondary Fe-oxides, gypsum (CaSO_4), and jarosite ($\text{KFe}_3^{+3}(\text{OH})_6(\text{SO}_4)_2$). Surface waters from TP5 have electrical conductivities (EC) ranging from 1.060 – 2.162 mS/cm with compositions dominated by Ca^{2+} , SO_4^{2-} , and HCO_3^- , whereas FRT surface waters have higher EC (1.027 – 2.890 mS/cm), notably higher concentrations of Fe^{2+} and SO_4^{2-} , and little to no HCO_3^{2-} . Water samples with pH between 7.05 to 8.05 have W concentrations

ranging from 5.3 to 26.3 $\mu\text{g/L}$, whereas all samples below pH 7.05 have concentrations below the detection limit of 300 ng/L. Unfiltered surface water samples have higher concentrations of both W and Fe than the filtered aliquots, suggesting that W is present as dissolved species but is also adsorbed to suspended Fe-bearing phases at neutral pH. Micro X-ray fluorescence of Fe-oxide rims of pyrrhotite grains in TP3 indicate the presence of W, which is also interpreted to be adsorbed. Further analyses are planned to investigate the apparent absence of W in the Fe-oxide phases from the FRT.

ALTERNATE RUNWAY MATERIAL R & D PROJECT

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Aircraft manufacturer Boeing has informed the airline industry and governments, worldwide, they will no longer be manufacturing or supporting gravel kits for the aircraft (727 & 737) and they will not be manufacturing a replacement jet aircraft to operate from gravel runways. The gravel kit equipped aircraft will become cost prohibitive to operate and maintain in the near future as the aircraft are expected to reach the end of their useful life, for scheduled passenger and freight service, in the next 4 to 6 years. The loss of jet service to remote communities will greatly increase the cost of transporting goods and services.

In Canada, currently asphaltic concrete is the type of material used for hard surfacing roads and airport surfaces. In the Arctic, asphaltic concrete suffers serious damage from harsh climatic conditions and permafrost heaving.

NORTHWEST TERRITORIES GEOLOGICAL SURVEY UPDATE FOR 2019

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Repairs are often difficult to complete in remote locations. The solution is to find alternative, environmentally friendly hard surface materials, equal to or better than asphaltic concrete and capable of withstanding Arctic conditions. The first material to be tested will be aluminum.

Aluminum has been in military use for over 40 years for temporary, roads, runways, bridges and helicopter landing pads, etc. The research and development test program will be conducted to confirm the suitability of aluminum for commercial use and to determine an alloy capable of withstanding Arctic climate conditions for a minimum period of 25 years.

As the world climate continues to warm air travel in arctic regions will become compromised as runways are more frequently damaged by environmental changes. Many of the modern aircraft currently being manufactured and those being designed for future service, require a hard surface runway. The purpose of the alternate runway material R & D test program is to find materials capable of being available to all community airports, no matter where they are located, to maintain safe air operations.

The objective of the test program is to identify cost effective, environmentally friendly materials that can be scientifically proven to aircraft manufacturers, operators and regulators, to be acceptable as an alternative material, for safe and reliable air operations, in place of asphaltic concrete.

Canada will be the first nation to develop alternate aircraft movement surface materials, the materials will provide cost effective and environmentally friendly options for use in the Arctic and remote locations throughout the world.

The Northwest Territories Geological Survey (NTGS) is a division of the Department of Industry, Tourism and Investment, Government of Northwest Territories. Core activities include geological mapping, airborne geophysical surveys, permafrost research, review of industry assessment reports, management and distribution of geoscience data, geological materials curation, administering the Mining Incentive Program, outreach and education, and mineral, petroleum and geothermal resource assessment. NTGS clients include industry, governments, non-government organizations, researchers, prospectors, and the public.

Much of the work of NTGS staff and research partners will be highlighted in talks and posters presented at this year's Geoscience Forum. This presentation provides complementary information that allows this work to be understood in broader contexts such as current and future geoscience knowledge needs for the NWT, response to public needs and concerns, and contributions to research partnerships and government action plans.

The NTGS is part way through a five year strategic plan and continues to receive advice from an external advisory committee. Our full slate of activities would not be possible without the support of universities, other GNWT departments, and federal government organizations such as CanNor. We acknowledge and appreciate these partnerships and collaborations.

ROADMAP TO MINERAL EXPLORATION & DEVELOPMENT IN THE INUVIALUIT SETTLEMENT REGION

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Mineral exploration has been limited in the Inuvialuit Settlement Region (ISR) as compared to other Northern regions. With the decline in the ISR of the oil and gas development industry, the Inuvialuit have begun to explore other avenues for responsible and sustained economic development, including the development of mineral resources. The Inuvialuit have always shown resilience through the insight of their elders, effectively adapting to cultural and social and economic changes while maintaining strong traditions and cultural connections to their lands. With this persistence, the Inuvialuit have assessed the economic potential of their traditional lands which encompasses 26% of the Northwest Territories landmass. While the region's geophysical location and population density may present obstacles in many business sectors, the region's abundant non-renewable resources offer massive economic development opportunities. This is particularly relevant within the ISR, where coal, diamonds, base and precious metals have been identified in many areas across the region.

The development of the Roadmap to Mineral Exploration & Development in the Inuvialuit Settlement Region has been to attract interest,

activity and investment to the region. The Inuvialuit offers their experience, the commitment and the capacity to work in partnership with potential mineral explorers and developers to find solutions and develop minerals in a manner that meets and respects the values and objectives of all interested parties. The ISR Mineral Roadmap is consistent in policy and direction with the Canadian Minerals and Metals Plan, the Northwest Territories Mineral Development Strategy, and the Inuvialuit Final Agreement and the Inuvialuit Land Administration. Through this document, the Inuvialuit invite and welcome those who have the foresight and energy to join the Inuvialuit in unleashing the vast mineral potential of this unique corner of Inuit Nunangat and Canada.

MARIAN WATERSHED STEWARDSHIP PROGRAM

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The Tłichq Government is working together with Wek'èezhìi Land and Water Board (WLWB) and other partners to develop the Marian Watershed Community-Based Aquatic Effects Monitoring Program. This is a community-based monitoring program that is being developed based on the questions and needs of the Tłichq people. Tłichq Lands had been under Moratorium since the signing of the Tłichq Agreement in 2005 and on June 1, 2013, the Moratorium was lifted as the Tłichq Wenek'e or Land Use Plan came into force. With the potential for future development of Tłichq Lands, the Tłichq people have expressed concern about impacts on the water and wildlife they are so dependent upon. The objective of the Marian Watershed Monitoring Program is to

begin collecting baseline information about the water and fish on Tłı̨chǫ lands and in locations the Tłı̨chǫ feel are the most important, prior to any major development pressure (such as the NICO mine by Fortune), and to continue collecting this data over time. Community members are being trained to collect samples, analyze the samples, and report findings back to the rest of the community members. A pilot project was conducted at Hislop Lake, upstream of the planned NICO Mine site, in the fall of 2013. This project included the training of eight community members and a field program where the newly trained Environmental Monitors worked with scientists to investigate the concerns of the elders and community members. A workshop was organized by the Department of Culture and Lands Protection (DCLP) in the spring of 2019 to bring back the results from the Hislop Lake camp and to develop a long term monitoring plan that truly addresses the concerns of the elders. We identified important field sites along the Marian River from Hislop Lake to Marian Lake, which will be visited on a four-year cycle. The ongoing program will facilitate enhanced understanding of fish health and water chemistry each year, ensure active monitoring of Tłı̨chǫ waters by Tłı̨chǫ people, and prioritize meaningful communication back to community members.

UPDATE OF NEW AND ONGOING MAPPING INITIATIVES IN THE SUNSET, NEWBIGGING, AND POINT LAKE AREAS, SLAVE CRATON, NORTHWEST TERRITORIES

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The Northwest Territories Geological Survey (NTGS) has been undertaking a series of 1:10,000 and 1:15,000 scale mapping initiatives in greenstone belts of the Slave craton. The projects focus on areas of elevated resource potential surrounding Sunset Lake, Newbigging Lake, and Keskarrah Bay on Point Lake. In collaboration with researchers and graduate students at Mount Royal University (Calgary) and the University of Saskatchewan (Saskatoon), a number of 1:2000 and 1:5000 scale detailed mapping transects have been completed. Together these projects are aimed at understanding the early evolution of the Slave craton, particularly the tectonic setting of emplacement of volcanic rocks and related sedimentary rocks and their relationship(s) to basement granitoids, to improve knowledge of ore-forming processes and to better understand controls on base metal and precious metal endowment.

Ongoing work in the Sunset Lake area (110 km east-northeast of Yellowknife) has taken a multi-faceted approach to enhance the knowledge of the litho- and chemo-stratigraphy of the Beaulieu volcanic belt and the Sunrise volcanogenic massive sulfide (VMS) deposit that it hosts. Bedrock mapping at 1:10,000 and 1:2000 scale and core logging has provided the details of the complex stratigraphy and geochemical signatures required for stratigraphic correlations within this volcanic belt, and has elucidated the VMS deposit model to help target future VMS mineral exploration in the Slave craton.

A new bedrock mapping initiative in the Winter Lake greenstone belt at Newbigging Lake (250 km northeast of Yellowknife) is designed to evaluate the nature of physical and temporal relationships between the major groupings of rocks in the belt including: 1) basement granitoids, 2) ca. 3.1 to 3.3 Ga felsic to intermediate volcanic rocks of the Newbigging Formation and related intrusions, 3) rocks of the ca. 2.85 Ga Central Slave Basement Complex, 4) the bimodal volcanic rocks of the Snare and Providence formations (likely equivalent to the ca. 2.73–2.66 Ga Kam and Banting groups respectively) and syn-volcanic diorite to gabbro intrusions, 4) Burwash Formation equivalent turbidites, and 5) <2605 Ma polymictic conglomerates of the Sherpa Formation. This initiative will establish additional absolute ages for rocks in and surrounding this greenstone belt, and the volcanic and sedimentary environments in which the rocks were emplaced, the diverse geochemical characteristics of these rocks, and their metallogenic history.

In 2019, a 65,000 line-km high-resolution magnetic survey was flown covering parts of NTS map sheets 086H, 086A, and 076E, including the Point Lake greenstone belt and surrounding granitoid basement complex. Ongoing bedrock investigations of the Point

Lake greenstone belt at Keskarrah Bay (330 km northeast of Yellowknife) continued in 2019 with a 1:15,000 scale bedrock mapping project focused on the southwestern arm. This distinct part of the greenstone belt consists of mafic to intermediate lavas, volcanoclastic rocks, and related intrusions. While this part of the Point Lake greenstone belt contains surface exposures of VMS-type mineralization, it lacks known VMS mineralization on the scale of IZOK Lake, which is located to the north in Nunavut, within the same seemingly contiguous volcanic rocks.

IMPLEMENTING AN APPLIED PERMAFROST RESEARCH PROGRAM: THE DEMPSTER–INUVIK TO TUKTOYAKTUK HIGHWAY RESEARCH CORRIDOR

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The Beaufort Delta region is one of the most rapidly warming areas on Earth. Societal consequences of permafrost thaw are significant as the area hosts the highest

density of Arctic communities and the longest road network constructed on ice-rich permafrost in Canada. The Dempster and Inuvik to Tuktoyaktuk Highways (ITH) comprise a 400-km corridor connecting the Beaufort Delta region with southern Canada. The highways traverse warm (0 to -2 °C) to cold (<-4 °C) permafrost, cross diverse terrain with varying ice contents, and intersect a range of hydrological and ecological environments. In this region, the diversity of sensitive permafrost environments and the rich legacy of research, scientific infrastructure, and traditional environmental knowledge facilitates the study of permafrost variability and Arctic change. The Dempster-ITH road corridor has provided a unique opportunity to develop a societally relevant, northern-driven permafrost research agenda to support planning and maintenance of infrastructure, regulation, and monitoring of climate change impacts and informed adaptation.

In 2017, the GNWT, in collaboration with Federal and Academic partners, implemented a state of the art ground temperature-monitoring network along the Dempster-ITH corridor. This, in combination with the maintenance of the Dempster Highway and recent design and construction of the ITH, has created a national legacy of permafrost geotechnical, terrain and geohazard information. The objectives of this program are to integrate existing and new data to synthesize physiographic, hydrological, thermal, and geotechnical conditions along the corridor, and to develop applied permafrost research projects that support planning and maintenance of this critical northern

infrastructure. In this presentation, we highlight: 1) a collaborative research framework that builds northern capacity and involves northerners in the generation of knowledge and its application; 2) summaries of existing infrastructure datasets and their foundation for research; and 3) new projects that address emerging climate-driven infrastructure stressors. As the effects of climate change on permafrost environments, infrastructure and communities continue to increase, the need for northern scientific capacity and applied research to support engineering solutions, informed decision-making, climate change adaptation and risk management will become increasingly critical.

LEGAL DEVELOPMENTS RELEVANT TO MINERAL INDUSTRY 2019

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This session will highlight some of the top developments in Indigenous, Environmental and Regulatory law in the Northwest Territories in 2019, including the following legislation passed by the 18th Legislative Assembly:

- Mineral Resources Act
- Protected Areas Act
- Environmental Rights Act
- Public Land Act
- Protected Areas Act

The session will give a short overview of the legislation and discuss highlights of importance to the minerals industry.

CARBON AND NITROGEN ISOTOPIC SIGNATURES IN THE DEVONIAN CANOL FORMATION: IMPLICATIONS FOR PALEODEPOSITIONAL CONDITIONS

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In sedimentary successions, the carbon isotopic composition of organic matter and bulk nitrogen isotopic composition are influenced by several factors, including isotopic signatures of carbon and nitrogen sources, carbon and nitrogen assimilation pathways of primary producers, microbial degradation of organic matter, and thermal maturation of organic matter. Here we used nitrogen and carbon isotopic profiles to shed light on the paleoenvironmental conditions and biogeochemical processes that operated during deposition of the Canol Formation, an organic-rich mudstone present in the Central Mackenzie Valley and Mackenzie Mountains of the Northwest Territories. In this study, samples were collected every two metres through the Canol Formation in the ConocoPhillips N-20 core from the Central Mackenzie Valley and analyzed for $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ composition. $\delta^{15}\text{N}$ values ranged from -3.7‰ to -0.6‰ . These isotopic values are characteristic of N_2 fixation, and suggest that diazotrophic organisms (e.g., certain

cyanobacteria species) were the dominant primary producers at the time. These results imply that NO_3^- and NH_4^+ were likely limited in surface waters because N_2 fixation consumes more energy than NO_3^- and NH_4^+ assimilation. The $\delta^{13}\text{C}$ values range between -28‰ to -30‰ , falling into the $\delta^{13}\text{C}$ range of many types of primary producers that include modern cyanobacteria. Two trends are apparent in $\delta^{13}\text{C}$: moving stratigraphically upward through the Canol Formation, a decreasing trend in $\delta^{13}\text{C}$ from about -28‰ to -30‰ is observed, followed by an upward increase in $\delta^{13}\text{C}$ from about -30‰ to -26‰ near the top of the Canol Formation and its transition into the overlying Imperial Formation. These shifts do not match trends in vitrinite reflectance, indicating that they were not produced by variations in thermal maturity. Similarly, the observed trends in $\delta^{13}\text{C}$ are not apparent in the $\delta^{15}\text{N}$ profile, which implies that they were not likely a result of changes in the proportions of different types of primary producers, because this should also affect $\delta^{15}\text{N}$ values. The observed trends are better explained by changes in the carbon source of primary producers or changes in paleoproductivity. Gaining insight into the conditions that led to the accumulation of this succession enhances our understanding of the controls on organic matter accumulation and preservation in organic-rich mudstone units, and specifically, the Canol Formation's potential as an unconventional resource target.

THE FURY AND HECLA
GEOSCIENCE PROJECT 2019:
A SUMMARY OF
PRECAMBRIAN BEDROCK
MAPPING, NORTHWESTERN
BAFFIN ISLAND, NUNAVUT

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The Fury and Hecla Geoscience project is a multiyear initiative by the Canada-Nunavut Geoscience Office (CNGO) in collaboration with Canadian universities and Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC). The goals of this project are to collect geological data from an area of Baffin Island that remains largely unmapped. Specifically, aeromagnetic geophysical data, bedrock, and surficial data was collected in order to constrain crystallisation ages and metamorphic events, to characterise sedimentary deposition, to record glacial dynamics, and to assess economic potential.

Field observations and preliminary interpretations from the 2019 bedrock mapping program are presented here. The project area is located north of the Fury and Hecla Strait between the communities of Igloolik and Arctic Bay. The study area comprises nine 1:250 000 National Topographic System (NTS) map sheets (37C, F,

47C-H and 48A), which covers an area of approximately 300 x 300 km.

Bedrock in this area is part of the ca. 3.0-2.5 Ga Committee Bay Fold belt, part of the northern Rae Domain, comprising Archean to Palaeoproterozoic orthogneiss and greenschist- to upper amphibolite-facies supracrustal belts. In the 2019 Fury and Hecla field area specifically, bedrock is composed of orthogneiss basement with remnants of supracrustal assemblages and minor ultramafic intrusions. Late syenogranite dykes, sills, and plutons; mafic dykes; and syenogranitic pegmatite dykes are also pervasive throughout the area. The orthogneiss basement is granodioritic to monzogranitic in composition with sporadic and deformed mafic enclaves. Structurally, it has a range of fabrics from weakly foliated, to gneissic with well-defined bands, to highly deformed (folded, boudinaged, faulted). The basement has a low magnetic signature containing sporadic mineralisation of pyrite, and a single occurrence of molybdenite, and malachite-chrysocolla. In the eastern portion of the study area porphyritic- to porphyroclastic, locally megacrystic, monzogranite is present. Supracrustal panels are uncommon and include banded iron formation (BIF), and quartzite. In the central portion of the map area, a 15 x 3 km magnetic anomaly outlined from the geophysical survey is identified as a tightly folded BIF. The exposed BIF includes sections of crenulated and folded quartz-magnetite layers with horizons of coarse-grained specularite, sections with massive and coarse magnetite, and sulphide-rich gossans. Ultramafic intrusions are uncommon, including local showings of serpentinised peridotite that may potentially be used as carving stone. Late NW-SE trending gabbroic dykes related to the ca. 723 Ma Franklin igneous event crosscut the entire field area and are easily observable on the geophysical survey. Syenogranite pegmatites crosscut all rock-units with preferred orientation. These pegmatites are commonly

zoned and can display graphic and perthitic textures.

Future work will include the submission and interpretation of geochemical, geochronological, and assay analyses by the CNGO and graduate students. All field data from 2018 and 2019 will be compiled for research purposes and the creation of Precambrian bedrock maps.

GSC'S GEO-MAPPING FOR ENERGY AND MINERALS PROGRAM (GEM): RESULTS FROM 12 YEARS OF NORTHERN GEOSCIENCE

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The Geo-mapping for Energy and Minerals (GEM) program, carried out by the Geological Survey of Canada (GSC) in collaboration with partners, lays public geoscience foundations for sustainable economic development in Canada's North. The 12-year (2008-2020) \$200 million dollar collaborative program has been providing modern, public geoscience that is setting the stage for long-term decision making related to responsible land-use and

resource development. Geoscience knowledge produced by GEM supports evidence-based exploration for new energy and mineral resources, and enables Northern communities to make informed decisions about their land, economy and society.

GEM's success comes from the close collaboration between the GSC, provincial and territorial geological surveys, communities and Northerners. Results include close to 2000 publications, 500 maps, 400 engagement sessions with communities and their organizations, one million line-km flown on geophysical surveys. It is clear the GEM products provide a critical first step for a better scientific understanding of Canada's northern geology, and help promote sustainable economic and social development. Since the program's inception in 2008, GEM has also supported Canadian geoscience initiatives by providing about 50 grants to academia, colleges and Northern communities.

GEM studies have economic impacts across the north – from identifying mineral expansion areas, such as gold in the Yukon and Nunavik/Labrador, to identifying areas in the Northwest Territories previously thought to have little resource value. In addition to the economic opportunities, GEM continues to promote geoscience through engagement with Northern communities, along with hosting community learning opportunities, including a GEM-led field school in Taloyoak, Nunavut.

GEM also had impacts on Northern land-use planning. The Ukkusiksalik National Park in Nunavut was expanded by 327 km² after an exchange of land between the Government of Canada and the Kivalliq Inuit Association (KIA) that was informed by results from GEM. The transfer will result in the conservation of culturally and archaeologically significant land that will benefit all Inuit and Nunavummiut.

The GEM program has improved geological research capacities through the development and refinement of remote predictive mapping methodologies. Other unexpected discoveries, such as the identification of the world's oldest fungus fossil in shale samples taken from Tuktut Nogait, Northwest Territories, as well as evidence of a previously unknown exoplanet strike found in field samples from Nunavut, were also facilitated by this program.

The speaker will present an overall summary of the realizations accomplished during these 12 years, as well as how GEM knowledge products are and will be disseminated in the near future.

GEM will be completed in 2020, but the research and results generated from this program will have lasting benefits in the North for decades to come. The GSC has undertaken a program planning initiative to plant the seeds for a successor, new collaborative geoscience initiative in the North, beyond 2020, which will be touched upon.

MOBILITY OF ARSENIC IN MINE IMPACTED SUB-ARCTIC LAKE SEDIMENTS

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Sediments are widely used as environmental archives to reveal historical trends in

contaminant deposition at lakes surfaces. However, some elements, such as arsenic (As), will not remain stable in the sediment after their initial deposition. Their redistribution is controlled by diagenesis, which represents physical mixing, biological processes and chemical reactions that transform sediments after deposition. In order to obtain a reliable historical record from sediment cores, the effect of diagenesis must be first quantified. To this end, pore water concentration profiles represent sensitive indicators of diagenesis that can be interpreted to estimate the extent to which diagenesis alters solid-phase distributions.

The main objective of this project is to use the sediments as environmental records to determine the extent and history of As contamination caused by the activities of the Giant Mine, near Yellowknife. We first determined the extent of As diagenesis in 8 lakes along an 80 km north-west transect away from a single point source of atmospheric As emission. We visited the lakes in June 2018 and May 2019 to collect a sediment core and pore water samples. Pore water was extracted directly from the cores using Rhizon lysimeter with a 0.2 mm membrane and dissolved As concentrations measured by inductively coupled plasma with mass spectrometry (ICP-MS).

Diagenetic modelling of the As concentration profiles in the pore water revealed that As fluxes ranged from 39,5 $\mu\text{mol}/\text{m}^2\cdot\text{yr}$ close to the mine to -27 $\mu\text{mol}/\text{m}^2\cdot\text{yr}$ at 80 km, decreasing with distance. At the 40 km mark, the sediment switches from a source to a sink of As to the water column. Maximum concentration of As reached in the pore water of each lake studied shows a decrease in concentration with the distance from the mine.

Correction for diagenesis revealed that up to 46% of the historical As had been remobilized

by diagenesis. To our knowledge, this is the largest correction reported so far in the literature and is in line with previous evidence that interpreting sedimentary records in terms of historical deposition must be done after accounting for diagenesis. Reconstruction of the atmospheric inputs shows a peak in As concentration in 1950, which coincides with the timing of elevated As emission from Giant Mine operations.

IS THERE A RELATION BETWEEN TUNGSTEN DEPOSIT FERTILITY AND BORON-RICH MELTS?

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Magmatic-hydrothermal systems are associated with a wide range of geodynamic settings that can be related to critical economic resources. Tungsten skarns deposits are formed by the magmatic-hydrothermal processes involving the interaction of metal-rich fluids issued from a highly differentiated pluton with the surrounding calcareous country rocks. In tungsten skarn deposits, the magmatic-hydrothermal transition is directly followed by tourmalinization, often visible on the margins of scheelite-mineralized quartz veins. Tourmaline, which is the most common boron-bearing mineral, is ubiquitous in hydrothermal ore deposits and is useful as a tracer of magmatic-hydrothermal processes.

However, whether boron plays an active role in the fertility of magmatic systems remains unclear. The magmatic-hydrothermal processes that control the timing of tourmaline crystallization and its relationship to scheelite mineralization are still to be defined.

In this study, the properties of the most primitive fluids identified in the Lened W skarn deposit, Northwest Territories, Canada, have been used to i) model the compositional evolution of fluids during fractional crystallization of the source magma, and ii) determine its impact on both the magmatic and hydrothermal processes in this system. Lened is one of three skarn deposits that comprise the W belt of the Canadian Cordillera, and it is the most boron-rich deposit of the system. The Lened deposit comprises tungsten-rich (scheelite) calc-silicate skarn and quartz veins, as well as emerald prospects, which are spatially related to a multiphase two-mica granite pluton. Tungsten mineralization is hosted both by the limestone facies and the pluton. The most primitive fluid identified in quartz at Lened is characterized by a dominant carbonic phase and a low-salinity aqueous phase with sassolite (H_3BO_3) daughter crystals, suggesting the system $CO_2-H_2O-NaCl-H_3BO_3$. Microthermometry, Raman spectrometry, and LA-ICP-MS results are used to refine the fluid salinity and solute composition.

Boron (0.5 wt. % B in this study) increases the H_2O solubility of a melt, and decreases melt viscosity, allowing residual magmas to crystallize at temperatures down to 600°C. Decreasing the viscosity of the melt as well as its solidus temperature (i) facilitates crystal-melt separation and therefore fractionation, enhancing extreme rare-element enrichment in the residual melts, and (ii) enhances the generation, extraction, and migration of the melt from its source region.

From our observations and previous studies,

this study models the composition of fluids associated with a boron-rich melt during fractional crystallization and aims to constrain tungsten behavior as the melt crystallizes.

GOLD MINERALIZATION AT THE CANTUNG W-CU SKARN: OUR PRESENT LEVEL OF UNDERSTANDING

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Located within the Canadian Cordillera in the Northwest Territories and approximately 400 km to the northeast of Whitehorse, Yukon Territory is the gold-bearing Cantung W-Cu skarn. It is genetically associated with a group of Mid-Cretaceous felsic plutonic suites known as the Tombstone-Tungsten suite, which intruded into the ancient North American continental margin resulting in the formation of a range of types of magmatic-hydrothermal systems. At Cantung, a peraluminous biotite monzogranite intruded into Neoproterozoic to Paleozoic passive margin sedimentary rocks belonging to the Selwyn Basin.

Gold was identified in samples from this study within both sheeted quartz veins and hydrous (Actinolite-Biotite-Pyrrhotite) skarn. Previous researchers have extensively studied fluid inclusion assemblages from these quartz veins and the results show generally two types of inclusions: H₂O-CO₂-NaCl±CH₄ inclusions along

with aqueous brine inclusions. Early aqueous-carbonic inclusions followed by mild-moderate salinity aqueous brine inclusions is often observed within some of the world's most well-known intrusion-related gold deposits.

Previous research on fluid inclusion assemblages from the hydrous skarn are also extensive, however interpreting the results are slightly more problematic. Early interpretations on the temporal relationship between each of the different skarn assemblages suggested they formed as part of a single mineralizing event. The dominant fluid inclusion assemblages found in most skarn minerals were non boiling mild-moderate salinity brines, but H₂O-CO₂-NaCl±CH₄ fluid inclusion assemblages were also identified, with those from hydrous skarn assemblages having the highest concentrations of CH₄.

Gold within both the sheeted quartz veins and the hydrous skarn both occur along with an assemblage containing native bismuth, bismuth tellurides and selenides, as well as various sulfosalts. The textures exhibited by this assemblage suggests they precipitated from hydrothermal fluids as low-temperature polymetallic melts, often remaining molten until long after the growth of silicates had ceased. The capacity of these Bi-Te-Se-S melts to precipitate directly from hydrothermal fluids and their potential to sequester gold from fluids which are undersaturated with respect to gold has been reproduced using thermodynamic calculations as well as experimentally. The data collected by other researchers in combination with our new data has helped produce an updated model of the timing of multiple mineralizing events and their potential relationships to the nearby intrusives. The results of U-Pb geochronology suggest that formation of the W-Au mineralized sheeted quartz veins preceded the formation of all skarn facies. They also suggest that the various skarn assemblages were not part of a single hydrothermal event, but rather each comprised a distinct mineralizing event with the gold-rich

hydrous skarn being the youngest. These results highlight just how much more work is required to fully comprehend all the aspects of the magmatic-hydrothermal history at Cantung.

GAHCHO KUÉ MINE UPDATE

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Gahcho Kué Mine is owned as a joint venture between Mountain Province Diamonds Inc. and De Beers Canada Inc. Located about 280 km northeast of Yellowknife, it is Canada's newest diamond mine and the world's largest in the last 14 years. After two years of construction, commercial operations began in September 2016. As the mine enters into its fourth year of operation, De Beers is pleased to provide an update on the current mine operations, updated mine plan, safety, environment, and social performance.

NORTH AMERICA'S LARGEST ICE ROAD - TIBBITT TO CONTWOYTO WINTER ROAD JOINT VENTURE

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The Tibbitt to Contwoyto Winter Road (TWCR) is North America's largest ice road network that directly supports the operating

diamond mines in the Northwest Territories. Operated by a Joint Venture between the Diavik Diamond Mines Inc, Dominion Diamond Mines ULC and De Beers Canada Inc., the ice road has an annual operating budget of \$21 to 22 Million. The ice road is built through advanced flooding technologies, ice profiling radar and quality assurance engineering. Overseen by the Joint Venture, the ice road is constructed and maintained by 170 experienced personnel, 24 hours a day, operating out of three camps. Over the past five years, a yearly average of 8336 loads (281,363 tons) were transported using the Tibbitt to Contwoyto Winter Road. The TCWR Joint Venture is a unique example of collaboration in the North's mining industry and represents a critical lifeline to the success of the NWT's diamond mines.

RECONSIDERING THE BACKBONE RANGES FORMATION, A PROBLEMATIC EDIACARAN-CAMBRIAN UNIT IN THE MACKENZIE MOUNTAINS, NW CANADA

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The Backbone Ranges Formation is widely distributed in the Mackenzie Mountains of northwestern Canada. From its type area in NTS 95L (Glacier Lake map area) it has been mapped north and west along strike through six 1:250 000 map areas, to the easternmost Yukon (eastern NTS 106C). In its type area, the Backbone Ranges Formation is more than 1 km thick, lies unconformably upon the Ediacaran-

aged Sheepbed Formation, and consists of a basal siliciclastic member, a middle carbonate member, and an upper member of cliff-forming quartz arenite. None of the members has yielded fossils in the type area. Early workers treated the Backbone Ranges Formation as the oldest Cambrian unit above the sub-Cambrian unconformity. Later workers recognized a karstic unconformity atop the middle member, and suggested that the lower two members were Ediacaran and the upper member Cambrian. Detailed correlations with more distally deposited Ediacaran units (Windermere Supergroup) and pre-trilobite Cambrian formations remained uncertain.

In Bonnet Plume Lake map area (NTS 106B), the lower and middle members of the Backbone Ranges Formation resemble their manifestations in the type area, but the upper member contains previously unrecognized internal subdivisions. In ascending order, these are: a semi-resistant unit of maroon, tan, and grey sandstone and siltstone; a recessive package dominated by brown siltstone; a resistant carbonate marker that is a few metres thick in the study area but thickens markedly to the south and west; a recessive unit of brown siltstone and sandstone; and a unit dominated by cliff-forming quartzite. New occurrences of Ediacaran megafossils and Cambrian trace fossils suggest that the Ediacaran-Cambrian boundary is at the top of the carbonate marker, which likely correlates with the Risky Formation. Regionally, the top of the Risky Formation is a karstic, unconformable contact that delineates both the top of the Windermere Supergroup and the sub-Cambrian unconformity.

The new work emphasizes several issues with the Backbone Ranges Formation. First, the formation contains two unconformities (top of middle member; top of carbonate marker in upper member). Second, because the new

units just described are subdivisions of the upper member, they must at present be treated as submembers, despite being regionally mappable and as thick as many formations in the Mackenzie Mountains. Third, it is undesirable to have the top of a supergroup be correlative with the top of a submember in the same region, as is implied by correlation of the sub-Cambrian unconformity. There is a long-standing need for revision, and probably abandonment of the Backbone Ranges Formation. On updated GSC maps for northern NTS 106B (in progress) the lower and middle members will be assigned new formation names, as will the subdivisions of the upper member. The new units will permit more detailed mapping of geological relationships, while contributing to more precise Ediacaran-Cambrian correlations and tectonic models in the Mackenzie Mountains and regionally.

UPDATES TO THE NWT'S PETROLEUM LEGISLATION

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The Government of the Northwest Territories, led by the Department of Industry, Tourism and Investment (ITI), has taken the first steps to modernizing its petroleum laws. ITI completed the development and proposal of amendments to the Petroleum Resources Act and the Oil and Gas Operations Act in accordance with strategic policy directives such as the Petroleum Resources Strategy and under the mandate of the 18th Legislative Assembly.

ITI worked closely with the Intergovernmental Council Secretariat, Indigenous governments and organizations, industry representatives, and

other key stakeholders throughout the development of these amendments. This process included community visits across the NWT, targeted stakeholder meetings, and a multi-platform engagement campaign.

With the use of policy and research work completed, ITI drafted two bills containing amendments which can be broken into three categories: administrative and technical improvements, transparency and public accountability, and significant discoveries. Those bills - Bill 36: An Act to Amend the Petroleum Resources Act and Bill 37: An Act to Amend the Oil and Gas Operations Act – were introduced in February 2019 and received assent in August 2019.

This presentation will provide an overview of the legislative initiative through its completion and passing in the Legislative Assembly and next steps, including coming into force dates and implementation.

IDENTIFICATION OF PHYSICAL AND CHEMICAL PROCESSES IMPACTING WATER QUALITY ALONG THE INUVIK TO TUKTOYAKTUK HIGHWAY (ITH)

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As part of the project's Aquatic Effects Monitoring Plan and Surveillance Network Program (AEMP/SNP), the GNWT must monitor water quality, upstream and downstream of highway water crossings along

the ITH, and around the granular source pits used for highway construction. Monitoring results are compared to water quality objectives (WQOs) defined in the AEMP/SNP, and the data are interpreted to provide an understanding of physical and chemical processes contributing to observed water quality, such as metal leaching, permafrost degradation, and introduction of suspended sediment load from the granular materials. Monitoring has been carried out annually since 2014 during the open water season. The presentation will include an overview and key results of the AEMP/SNP as it relates to water quality monitoring.

Monitoring results up to 2018 have shown that total concentrations of several parameters (e.g., DO, pH, aluminum, iron, copper) at downstream water crossing sites which do not meet the WQOs are linked to similar background concentrations. Pit drainage has been linked with recurring exceedances of several parameters including turbidity, sulphate, nitrate and nitrite, selenium and uranium with respect to the WQOs. These exceedances are likely linked to erosion and/or leaching of the granular materials, as well as degradation of permafrost and slumping of the pit walls.

Dissolved element water quality monitoring data from the ITH sites have been compared to published data of lakes impacted and unimpacted by thaw slumping, a process which is indicative of permafrost degradation. Comparing ratios of major cations to major anions ((Ca+Mg)/(Na+K) to SO₄/Cl) SRK has identified signatures in major ion chemistry that may be linked to permafrost degradation. Our interpretation indicates that permafrost degradation has and may still be occurring along some sections of the highway and at some of the granular source pits.

Temporal changes of (Ca+Mg)/(Na+K) and SO₄/Cl ratios indicate that samples from highway water crossings are shifting towards

Na-K-Cl-SO₄ dominated waters which suggests a decreasing influence of permafrost disturbance, which is likely due to freezeback. A similar assessment of temporal changes of (Ca+Mg)/(Na+K) and SO₄/Cl values for the pit drainage is however, not straightforward given a higher influence of weathering of granular material. Our interpretation suggests that pit drainage is dominated by Ca+Mg-SO₄-HCO₃ chemistry and that leaching processes at most pits have been relatively constant over multiple seasons. Increasing trends of chemical indicators at two pits however, indicate that the rate of permafrost disturbance may be increasing. Further monitoring and correlation to geotechnical data are required for a complete assessment of permafrost disturbance, and to assess the potential for further impacts.

GEOLOGICAL INVESTIGATIONS OF THE WESTERN MARGIN OF THE SOUTH RAE CRATON, NONACHO LAKE AREA (NTS 75F), NWT: BEDROCK MAPPING, U-PB GEOCHRONOLOGY, METALLOGENY, SEDIMENTOLOGY AND STRUCTURAL EVOLUTION

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The Rae craton is part of the Canadian Shield and is separated from the Slave craton and the Buffalo Head Terrane by the Thelon Tectonic Zone (TTZ) and Taltson Magmatic Zone (TMZ). The least understood region of the Rae craton is its western margin, exposed in southeastern Northwest Territories (NWT). At least two periods of collision along the western margin of the craton have been identified; the ~2.5-2.3 Ga Arrowsmith orogeny and the 1.9-1.93 Ga TTZ/TMZ orogeny. However, many uncertainties remain regarding the tectonic evolution of the area.

As part of a concerted effort to update existing knowledge of the South Rae craton, the NWT Geological Survey is leading a thematic

geoscience program, now in the second of three years, in the Nonacho Lake area. This area includes the western flank of the South Rae craton between the Porter domain in the core of the Rae craton, to the east, and the TMZ, to the north and west. In the Nonacho Lake area, Archean and Proterozoic gneissic basement is unconformably overlain by clastic rocks of the ~1.9 Ga Nonacho Group. Preliminary results are reported on herein for U-Pb geochronology, metallogeny, sedimentology, and structural-evolution studies undertaken during the 2019 field season.

Reconnaissance U-Pb geochronology of basement orthogneisses and granitoids documents ca. 2.60 Ga magmatism typical of the Rae craton, and 2.5-2.3 Ga magmatism and metamorphism overlapping in age with the Arrowsmith orogeny and ca. 2.5 Ga igneous rocks of the Queen Maud block (QMb). Considered with field mapping data, these results suggest that ca. 2.5 Ga rocks of the QMb and/or Taltson basement complex extend into the Nonacho area, well inboard of the TMZ.

Preliminary work on the sedimentology of the Nonacho Group reveals evidence for significant intervals of marine deposition in the lower, sandstone-dominated units of the Nonacho Group, previously thought to be entirely fluvial-alluvial-lacustrine. Marine influence is inferred from the presence of thick successions that have abundant hummocky cross-stratification and wave ripples topping most beds, local herring-bone cross-stratification, and tidal bundles.

Preliminary results of structural evolution studies show that at least three major shear zones are present between the dominantly Neoproterozoic Porter domain and dominantly Paleoproterozoic TMZ. Two of these shear zones record greenschist grade sinistral strike-slip or oblique normal-sinistral movement which occurred after the deposition of the <1.9

Ga sediments of the Nonacho Group and post-date at least one generation of regional folding and hydrothermal activity.

At least four mineralogically and temporally distinct mineral assemblages record a widespread and long-lived post-Nonacho hydrothermal system: i) pink to reddish feldspar-quartz±magnetite, ii) epidote ± hematite, iii) black chlorite ± U, Au, Ag, Cu-sulphides, specular to black hematite, and muscovite, and iv) quartz ± Cu, Zn, Pb, sulfides, Ag, barite, carbonate, and fluorite. While it is too early to classify the numerous mineral occurrences of the Nonacho area, it is noted that the various occurrences share similarities with IOCG, skarn, Manto-type, unconformity-type U, and vein-hosted base metal deposits.

LOST BUT NOT FORGOTTEN: RECOVERING AND COMPILING HISTORIC DATASETS TO ADVANCE MODERN EXPLORATION IN THE PINE POINT MINING CAMP, PINE POINT, NORTHWEST TERRITORIES, CANADA.

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Over the last few decades, digital data management and compilation have become essential to exploration and mining ventures. A

significant impediment to mineral exploration is the lack of raw digital data from previous surveys resulting in significant re-work, financial burden and time delays. The closure of Cominco Ltd.'s operations in the Pine Point Mining Camp happened at the very edge of the digital age in the late 1980s. At this point, over 20,000 drill holes had been recorded on analog magnetic tape for long-term storage. In addition to the magnetic data, approximately 1 million meters of core were left abandoned in a reasonably organized lot. Using this existing data, Osisko Metals Incorporated has recovered, categorized, and initiated the verification of mining and exploration data collected over half a century. This dataset has been cross-referenced with physical locations and, in some cases, preserved core and logs. Site geologists now have access to exploration and production drill hole data spanning 50 years. By reviewing and enhancing this database, geological interpretation can be significantly improved and revised. Historic collar surveys are within 5-10m of their true location on modern coordinate projections. To further validate and enhance the quality of the database, the historic collars in key areas are being re-surveyed with a Differential Global Positioning System (DGPS) tool, able to determine actual location with cm-scale accuracy. Due to the limited recovery and storage of geological information in the magnetic tapes, the database is being substantially augmented by a high-volume historic core re-logging program. The cataloguing of the affectionately named "Core Graveyard" has resulted in a digitally preserved core library where the locations of each stored hole as well as the relative condition are known. This catalogue allows geologists to target orphaned drill holes and search the core for mineralization or favorable ground in context of modern interpretations. In many cases, the preserved core can be used for reconnaissance of target areas based on mineralization trends or geometries.

Incorporating the recovered logs into GIS and data processing programs, many obstacles present with transcription and interpretation are removed. The most important uses for these datasets are advanced 3D modeling of new data with recovered old data, validation of historical data, and recalculation of Mineral Resource Estimates. Furthermore, developing new exploration targets is therefore based on the identification of new controls on mineralization, leading to potential new discoveries. By integrating these crucial aspects, a workflow can be created for evaluating and drilling promising targets. Work to extend known deposits begins with visualizing historic drill hole data in GIS/3D GIS programs. Positive results can be followed by determining which holes should be reviewed from the Core Graveyard, including re-logging, resampling or extending sampling intervals. Re-logging of historic holes focuses on: highlighting depth to target, mineralization type(s), horizons of interest, and identifying under explored or undervalued areas that show promise for new drilling targets. This approach has now been tested at the Pine Point property with promising initial results, which will be further explored in the future.

FROM SCIENCE TO DECISION- MAKING: THE ROLES OF SCIENCE, HAZARD AND RISK ASSESSMENT, AND MITIGATIVE MEASURES IN THE MANAGEMENT OF GEOHAZARDS ALONG THE DEMPSTER HIGHWAY CORRIDOR

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Effective management of geohazard risks within and outside the right-of-way of the Dempster Highway, in Yukon and Northwest Territories, requires an appreciation for the sequential and synergetic roles of foundational science, hazard and risk assessment, and mitigative measures.

Foundational science and engineering embody the primary phase of data collection and analyses by which knowledge fundamental to understanding geohazards is developed. This geoscience information may be collected at regional, local or site scales and is often spearheaded by federal (Geological Survey of Canada) or territorial (Yukon or Northwest

Territories Geological Surveys) geological surveys and academic institutions. Hazard assessment then involves the application of knowledge to estimate the probability and magnitude of particular geohazard processes, in turn, supporting qualitative or quantitative evaluation of the risk posed to public safety and/or highway infrastructure. Hazard and risk assessments in northern Canada are typically conducted by geoscience or engineering consultants specialized in geohazard processes in permafrost terrain. Typically, the datasets and theoretical understanding of processes generated by foundational science are applied to guide professional assessments and justify recommended follow-up actions. Mitigative measures are techniques used to manage the risk posed by geohazards within and/or outside the highway right-of-way. Surveillance monitoring is a tool that can be implemented to inform maintenance requirements and public safety. This may precede development of engineered solutions for risk mitigation, typically devised by consultants and suppliers based on the results of the prior risk assessment.

Application of this risk management framework is demonstrated in association with a retrogressive thaw slump about 500 m upslope of the Dempster Highway on the Peel Plateau at km 28.5 in the Northwest Territories. Scientific studies examining landscape changes in slope stability and monitoring of off right-of-way phenomena informed highway infrastructure managers of potential risks and provided context to support the design of a proposed surveillance system to alert infrastructure staff of imminent impacts to the road embankment. An ongoing investigation of the risk posed by rapidly degrading ice-rich permafrost underlying the Dempster Highway, near Chapman Lake, Yukon, also showcases the application of the risk management framework. As climate stresses on highway, airport and community infrastructure in permafrost regions

grow, conducting fundamental science and integrating this knowledge base in risk assessment and the design of engineering solutions becomes increasingly important.

LITHALSA DEGRADATION, THERMOKARST DISTRIBUTION, AND LANDSCAPE EVOLUTION, NORTH SLAVE REGION, NORTHWEST TERRITORIES

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The Great Slave Lowland and Great Slave Upland ecoregions of the subarctic Canadian Shield are influenced by permafrost that has developed in a time transgressive manner throughout the Holocene with lake-level recession. Thermokarst in the region is commonly associated with the degradation of ice-cored mounds (lithalsas), which are numerous. Here we use site descriptions and air photos to document the distinct geomorphic signatures associated with degrading lithalsas and develop a conceptual model for lithalsa degradation, which builds upon an earlier model of lithalsa formation. Two main processes dominate lithalsa degradation: (i) subsidence indicated by ponded water with partially submerged standing dead trees, and (ii) colluviation of thawed sediments toward the lithalsa margin

that results in a rampart. Applying these diagnostic criteria to satellite image analysis, we found that lithalsas were once more widespread at higher elevations (Great Slave Upland), but the majority have degraded. The results suggest that lithalsas have been vulnerable to thaw throughout the Holocene, and explain, in part, the reduction of lithalsa abundance with increasing elevation. The conceptual model suggests that soil hysteresis effects would likely prevent re-initiation of lithalsa formation if permafrost were to re-aggrade in the future. Finally, high counts of intact lithalsas, degraded lithalsas, and thermokarst ponds within 15 m elevation of the Great Slave Lake shoreline indicate that this terrain is the most sensitive to climate warming and should be avoided by new infrastructure development.

DRIFT PROSPECTING APPLIED TO VOLCANOGENIC MASSIVE SULPHIDE (VMS) AND OTHER GREENSTONE BELT RELATED DEPOSITS EXPLORATION IN THE SLAVE GEOLOGICAL PROVINCE, NT.

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Drift prospecting applied to volcanogenic massive sulphide (VMS) and other greenstone belt related deposits is well documented. Case studies outline best practices for the use of indicator minerals, till geochemistry and gold grain recovery across Canada and other formerly glaciated terrain. While Nunavut's Izok lake

deposit has been the subject of such case studies, the Northwest Territories is notably absent from this body of literature. With the prospect of an all-season road crossing the Slave Geological province, the Northwest Territories Geological Survey has launched multiple efforts to support exploration in greenstone belt settings, including this multi-year till sampling campaign. This presentation outlines the indicator mineral and geochemical results from till collected during the summers of 2016 and 2017. A total of 155 till samples were collected and analyzed for indicator minerals and till geochemistry. Ninety-two of these samples were also analyzed for gold grain recovery. Till sampling sites were selected to outline contrasts between regional backgrounds and multiple historical metallic showings found on a rough transect from the Sunrise deposit to the south and the Point Lake area to the north. Both of these areas were also the subject of additional sampling to characterize local dispersal patterns.

Indicator minerals recovered in samples collected down-ice of known greenstone belt related mineralization include chalcopyrite, gahnite, spinel and rutile. Other potential indicator minerals such as scheelite, arsenopyrite, sphalerite and loellignite were less common but also recovered from samples of interest. Thirty-three out of the 92 samples analyzed for gold returned positive results ranging from 1 to 3 grains of irregular to abraded shape. The two best samples returned estimated gold values of 17.9 and 18.8 ppb from till. Those values correspond to known mineralization; respectively the TIP showing in the Camsell lake area and the Sunset deposit in the Beaulieu river area.

Till geochemistry was analyzed using ICP-MS after partial and near total digestion using the less than 0.063 mm size fraction. Cu, Ga, and Pb are found to be the most reliable indicator elements as they most commonly have anomalous values down ice of known

greenstone belt related mineralization. Ag, As, Bi, Cd, Fe, and Mn, though less commonly anomalous, also provided easily identifiable outliers. Interestingly, Co, Mo, U, Zn and REE anomalies were also identified. Multiple till samples anomalous in gold concentrations as well as indicator minerals are consistent with geochemical anomalies, such as in the Beaulieu River area, the Camsell Lake and in the eastern part of the Point Lake area. Indicator mineral, gold grains recovery and till geochemistry were all successful at identifying anomalies down ice of known bedrock mineralization, even in areas of thin and discontinuous till, commonly believed to be less conducive to drift prospecting in the Slave Geological Province.

LONG-TERM MEASUREMENTS OF PERMAFROST DEGRADATION AND GROUND SURFACE SUBSIDENCE IN THE MACKENZIE DELTA AREA FROM A NETWORK OF THAW TUBES

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Significant climate warming in the Mackenzie Delta area in the past few decades has resulted in increases in permafrost temperatures and thaw depths. In ice-rich permafrost, these increases result in differential ground surface subsidence that may damage infrastructure and alter ecosystems. The Geological Survey of Canada maintains a network of thaw tubes to

monitor long-term changes in active layer conditions in the Mackenzie Valley and Delta. We analyzed annual measurements (1991-2016) from a subset of 17 thaw tubes in the Mackenzie Delta region to investigate changes in thaw penetration (TP), ground surface (GS) elevation relative to a stable benchmark, and active-layer thickness (ALT). Over the whole study period, TP increased significantly at 10 of the sites, at a median rate of 0.5 cm a⁻¹ (min: 0.2, max: 1.5 cm a⁻¹), indicating progressive degradation of upper permafrost. Significant ground surface subsidence occurred at 10 sites, at a median rate of 0.4 cm a⁻¹ (min: 0.2, max: 0.8 cm a⁻¹), indicating melt of ground ice. These results highlight long-term permafrost degradation and subsidence of ice-rich terrain in the western Arctic. The measurements show that between ~5 to 38 cm of permafrost have thawed over 25 years at the sites, and ~5 to 20 cm of excess ground ice have melted. In contrast with TP, ALT increased significantly at only 5 sites, decreased at 4 sites, and was unchanged at 8 sites. In ice-rich ground, measured increases in TP can be more than double increases in ALT. For example, ALT increased by only 19 cm between 1994 and 2016 at a site near Inuvik, but TP increased by about 40 cm and was accompanied by 20 cm of surface subsidence. At sites with ice-poor permafrost, negligible settlement occurs, and increases in TP and ALT are similar. The observations further highlight that the degradation of ice-rich permafrost cannot be detected by traditional probing for active-layer thickness. The results have implications for forecasting changes to permafrost in Earth system models due to climate change. Simulations that do not account for ground surface subsidence may not adequately represent heat flow through the active layer/permafrost system and hydrological implications caused by thaw of ice-rich ground.

VERIFYING THE PROTECTIVENESS OF A POTASSIUM WATER QUALITY BENCHMARK

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Water quality modelling results predicted minor exceedances of the potassium water quality benchmark in the receiving environment downstream of the Ekati Diamond Mine. Concern was raised with the predicted minor exceedances and the protectiveness of the potassium water quality benchmark (i.e., 64 mg/L).

The Dominion Diamond Mines water quality benchmark for potassium was derived in accordance with Canadian Council of Ministers of Environment (CCME) requirements for establishing Type A water quality guidelines, as there were no existing water quality guidelines for this constituent. The derivation used a species sensitivity distribution with long-term toxicity test data from three species of fish, four invertebrates, and three plants or algae.

To provide the regulatory community with additional confidence in the long-term protectiveness of the potassium water quality benchmark (i.e., that adverse effects would not be expected if minor exceedances of the potassium benchmark were to occur) additional longer-duration toxicity tests were conducted. Toxicity tests were conducted to evaluate the chronic effects of potassium on the survival and growth of three laboratory test species in site

water; 28-day survival and growth test using the amphipod, *Hyalella azteca*; 28-day survival and growth test using the fingernail clam, *Sphaerium* sp.; 32-d survival and growth test using the fathead minnow, *Pimephales promelas*.

Standardized test methods were used or, in the case of the fingernail clam test, methods that are published in peer-reviewed literature. Potassium chloride was used to introduce potassium into the test solutions. The potassium addition took into account the potassium that was already present in the site water and supplemented to achieve treatment concentrations of 64, 80, 100, and 200 mg/L (as potassium).

Results from the toxicity tests for *H. azteca* were LC₁₀ (survival) of 143.3 mg/L, and IC₁₀ (weight) of 152.6 mg/L; for *Sphaerium* sp. were LC₁₀ (survival) of 81.5 mg/L, and IC₁₀ (weight) of >99.6 mg/L; and for *P. promelas* were LC₁₀ (survival), EC₁₀ (hatch, normal development), and IC₁₀ (biomass, length) of >208 mg/L.

The outcomes from the toxicity tests lend support that the water quality benchmark of 64 mg/L potassium is protective of the test species and continues to be appropriate for use as a water quality benchmark. There were no adverse effects observed in exposure to 64 mg/L potassium with any of the three test species. Further, the lowest tenth percentile point estimate, which is considered a no effect level by CCME was an LC₁₀ of 81.5 mg/L potassium; this value is 27% greater than the potassium water quality benchmark. The most sensitive low effect level from these tests was an LC₂₅ of 88.8 mg/L for survival of *Sphaerium* sp. over a 28-day period, which is 38% greater than the water quality benchmark.

WALK THE LINE: THE DELICATE BALANCE OF SETTING CLOSURE CRITERIA AND THE RELATIONSHIP WITH CLOSURE/POST-CLOSURE MONITORING

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In many jurisdictions, the development of a closure plan includes the development of closure goals, objectives and criteria. These are used to guide the transition of the site to the desired end land use, and demonstrate success. In some instances, particularly with sites that have a long mine life, these goals, objectives and criteria may need to evolve, to better reflect an achievable end land use, as well as criteria that are achievable and demonstrable. In other instances, sites must develop closure goals, objectives and criteria long after the start of operations. This means that the initial design of the operation may not be aligned with closure needs, and may not facilitate the transition to the desired end land use. At newer operations there are more opportunities to align design choices with closure goals and objectives, in a way that can benefit the transition to closure, end land use and eventual relinquishment of the site.

Both regulators and mine operators need achievable closure criteria, and the achievement of the criteria to be demonstrated in a realistic time frame. The setting of unrealistic or unachievable criteria may lock operators into years or decades of costly monitoring programs

and impede relinquishment of the site. In an extreme case, unrealistic closure criteria may serve to discourage operators from completing reclamation, as the bar is seen to have been set too high. Hence, there is a difficult line to walk, requiring cooperation between regulators and operators to achieve desired outcomes.

In selecting appropriate goals, objectives and criteria, it is critical to be able to have achievable criteria that match the achievement of the desired end land use.

Closure criteria must be:

- measurable or an easily discernable qualitative indicator;
- relevant to impacts from mining;
- indicative of a component of the targeted end land use; and
- able to demonstrate that the final closure configuration endures over many years or decades.

Including the perspectives of Indigenous communities can help in determining the closure priorities for the site and hence selecting appropriate closure criteria. In isolated settings the land is often returned to traditional Indigenous use post-closure, where the fundamental rights to hunt and fish are often of primary concern and necessitate adequate ecological functioning of the post-closure landscape. In this manner, local stakeholders can be a valuable resource when setting closure objectives and criteria and should be included in the development process.

This presentation provide a retrospective analysis of closure criteria for common mine environment components such as tailings, water quality, and vegetation, and a discussion of whether or not this balance is achieved.

OVERVIEW OF GEM2 QUATERNARY RESEARCH IN THE SOUTHWESTERN NORTHWEST TERRITORIES: A REGION WITH HIGH POTENTIAL FOR UNDISCOVERED ZN, PB AND CU

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As part of the Geological Survey of Canada's GEM2 Program, Quaternary geology and mineralogical studies of till and stream sediments were undertaken in the southwestern region of Great Slave Lake from 2017-2019. Multi-faceted research activities in the study area addressed the broad research question: "Is there potential for additional carbonate-hosted sulphide deposits under the thick glacial overburden between Hay River to Kakisa Lake and Fort Providence?"

Fieldwork involved surficial mapping of NTS sheets 85C, 85F and 85G and included till and

stream sediment heavy mineral sampling; no previous surficial mapping or surficial heavy mineral data existed for these areas. The project benefited from additional samples donated by the Northwest Territories Geological Survey collected as part of former Protected Area Strategy surveys. Heavy minerals were subjected to trace element geochemical and isotopic analyses to elucidate potential mineralization source types, and eliminate known sources (i.e., Pine Point). Our data and results indicate a strong potential for undiscovered Zn, Pb, and Cu mineralization occurring in bedrock concealed beneath Quaternary sediments in the region.

A better understanding of the surficial sediments and glacial history of the study area is achieved through several avenues of research. Stratigraphic sections of Quaternary sediments were mapped and studied in the upper Mackenzie River and Cameron Hills, and surface till samples were analyzed geochemically and for clast lithology content. Detailed stratigraphic and till micromorphological studies were undertaken at the abandoned M-52 pit at the Pine Point mine site, and in the Cameron Hills (which host impressive streamlined landforms for fast basal ice flow). Finally, a compilation of drillhole data and field data were used to construct isopach maps of the Quaternary sediment cover across the entire study and extended beyond to include the Pine Point mining district. The collected field data and results from this project bring considerable new insights including three main ice-flow phases, new age constraints on deglaciation and drainage of glacial Lake McConnell, and several new areas defined by till and stream sediment heavy mineral results, which indicate a high potential for buried mineralization.

EXTENDED CARE AND MAINTENANCE AND ZERO OCCUPANCY AT SNAP LAKE MINE: AN UPDATE

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The Snap Lake Mine is a former underground diamond mine operated by De Beers Canada Inc. (De Beers), located about 220 km northeast of Yellowknife in the Northwest Territories. The Snap Lake Mine operated from 2008 to 2015 and De Beers submitted the Final Closure and Reclamation Plan for the mine. The mine is currently in its fourth year of being managed in a state of Extended Care and Maintenance (ECM).

Activities during ECM include monitoring of water quality and other environmental parameters, collecting and treating effluent and making sure that water leaving the site meets water license requirements. Physical infrastructure such as the airstrip, roadways, buildings, processed kimberlite containment facilities and associated surface water infrastructure such as pumps, sumps and channels need to be kept in a safe and operable condition. After a trial-run of reduced camp occupancy in 2017, the site was fully winterized and demobilized in September 2018. This update will review the first seasonal zero occupancy at Snap Lake, as well as the work completed in spring/summer of 2019.

REMOTE MONITORING AT SNAP LAKE MINE

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The Snap Lake Mine is a former underground diamond mine operated by De Beers Canada Inc. (De Beers), located about 220 km northeast of Yellowknife in the Northwest Territories. The Snap Lake mine operated from 2008 to 2015, and entered a Care and Maintenance mode in December 2015. The mine is currently entering its fourth year of being managed in this Extended Care and Maintenance phase.

In order to ensure continual remote monitoring of certain key geotechnical, meteorological and air quality instrumentation and to enable visual observation of key infrastructure, work was done in 2018 to integrate new and existing monitoring instrumentation into the existing Campbell Scientific PakBus network. In this presentation De Beers will share a summary of this work, with the emphasis on the type of technology, detail of installation and integration of systems between the various pieces of instrumentation.

First we will discuss installation of the 5 data collection stations that relay geotechnical instrumentation information. The data collection system at each of the 5 stations consists of a solar panel, battery, data logger, and multiplexor and short-wave radio. To enable redundancy, a manual data collection via USB was added, in the event that remote communication with the stations is lost.

Second, an overview of the installation of camera monitoring stations as well as the communications protocol used for the integration of the weather and ambient air quality data transmitted via satellite will be presented.

While the focus will be on the technology and systems used for remote monitoring, and not the actual monitoring results per se, it is our intention to share this and some of the successes and challenges experienced during the first year of remote monitoring during zero occupancy conditions.

DEPARTMENT OF INDUSTRY TOURISM AND INVESTMENT RESOURCE DEVELOPMENT OUTREACH ACTIVITIES

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The Northwest Territories (NWT) has a long history of non-renewable resource development and surveys indicate that NWT residents generally have a favourable perception of mineral and oil and gas development. However, gaps in knowledge and misconceptions about this sector are common and undermine informed decision-making. The Department of Industry, Tourism and Investment (ITI) has implemented a number of outreach initiatives that aim to increase public awareness of resource development. Activities of particular note are: Introduction to Prospecting courses, Mining Matters educational and outreach

programs, and the Resource and Energy Development Information (REDI) initiative.

Since 2014, a total of 11 Introduction to Prospecting courses have been offered in Yellowknife, Hay River, Behchokò, Dettah, and Inuvik. During this two-day course, students learn about mineral exploration in the NWT, get first hand prospecting experience, and receive NWT prospecting licenses. Many participants later stake claims and some have even sold their properties to mineral exploration companies. Introduction to Prospecting courses are supported by a partnership between ITI, the Mine Training Society, and other industry partners that have included TerraX Minerals and Osisko Minerals.

ITI has partnered with industry, community and educational partners to deliver the Mining Matters programs in the Sahtú and Dehcho regions as well as Yellowknife and Hay River. Mining Matters is a charitable organization that provides mineral and geological programming to elementary and secondary school students, as well as professional development training to teachers across the country. Mining Matters student programs are designed for short term school visits based on the students' grade level. The programs compliment established curriculum requirements, and are worked out in advance between the schools and Mining Matters instructors. Mining Matters professional development workshops provide teachers with curriculum-linked resources including rock and mineral samples, mineral testing equipment, posters, student handouts, and games, along with lesson-plans and a tutorial of how to implement these resources in the classroom. Mining Matter programs were first offered in 2016.

REDI is an ITI-led initiative that requires multi-departmental participation as well as partnerships with various non-government

partners. ITI will continue to add additional partners as REDI evolves. REDI was formally launched as a tradeshow-style event at the Arctic Energy and Emerging Technologies conference in Inuvik in June 2017. Follow up events took place in Hay River (November 2017), Yellowknife (June 2018), Fort Simpson (October 2018), and Norman Wells (February 2019).

The success we have witnessed from these efforts would not have been possible without key partnerships with industry, academia, and other non-government organizations. Further partnerships will be needed to help meet the expanding community demand for resource development focused outreach.

CHIDLIAK PROJECT UPDATES

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The Chidliak exploration site was discovered in 2005 and acquired by De Beers Canada (De Beers) in September 2018. The Project is located on the Hall Peninsula of Baffin Island in the Qikiqtani Region of Nunavut and the closest communities are the Hamlet of Pangnirtung and the City of Iqaluit. The current Chidliak exploration site is not located within Inuit Owned Lands, Territorial or National Parks and is located entirely within Crown Lands. The current Chidliak exploration site includes 30 kimberlites two of which (CH-06 and CH-07) have been tested for grade and diamond value and are considered to be at an Inferred level of resource confidence.

De Beers is currently engaged in a concept study to evaluate various FutureSmart Mining

methods that would minimize environment impacts and enable relatively small kimberlites (diamond bearing rock) to be mined.

De Beers is conducting desktop and field studies to evaluate options for mining methods, infrastructure, processing, information technology, and employee work models. In parallel, environmental field programs were conducted in 2019 to advance the environmental data collected in 2009 to 2017 and to support the evaluation of mining options.

This presentation will provide a brief synopsis of the Project and work conducted in 2019 to advance the Project.

WATER MONITORING AT SNAP LAKE MINE

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The Snap Lake Mine (the Mine) is a former underground diamond mine operated by De Beers Canada (De Beers), located about 220 kilometres northeast of Yellowknife in the Northwest Territories. The Snap Lake Mine operated from 2008 to 2015, and entered a Care and Maintenance mode in December 2015. In February 2017, the Mine underground workings were decommissioned and allowed to flood, in December 2017, De Beers announced the intent to enter into final closure, and in March 2019, De Beers submitted the Final Closure and Reclamation Plan for the Mine. Water management has

always been an important component at the Mine and was considered in development of the Final Closure Plan to achieve the overall goal of “returning the site and affected areas around the Mine to technically viable and, where practicable, self-sustaining ecosystems that are compatible with a healthy environment and with human activities”.

Water management at the Mine has changed significantly since diamond mining operations ceased. During diamond mining operations, a large volume of water was pumped from the underground to the surface for management and release to Snap Lake and the downstream environment. This mine water was relatively high in total dissolved solids and total suspended solids and therefore had to be treated prior to discharge. Now that the underground is flooded, there is no longer a need to pump mine water to the surface and water management has been greatly simplified. Since 2017, small volumes of runoff water from the North Pile (a surface disposal facility that was used for processed kimberlite, waste rock, and non-hazardous solid waste during operations) is collected for management and release to the underground and to Snap Lake. Water quality and aquatic ecosystem monitoring has been conducted yearly since pre-mining. Results of these programs have informed adaptive management at the site and informed plans for closure.

The focus of this presentation is on water management and monitoring, for the Mine to the receiving environment, covering the history of the Mine to present and into planning for closure.

ASTRO GOLD PROJECT, MACKENZIE MOUNTAINS, NWT

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The Astro project is a new gold discovery located in the Mackenzie Mountains along the Northwest Territories (NWT) -Yukon border. The 250 square-kilometre project area is located 195 kilometres northeast of Ross River and six kilometres north of the Mile 222 airstrip at the end of the Canol Road in NWT. Evrim Resources, in partnership with Newmont-Goldcorp, conducted two field seasons of generative exploration in the Misty Creek Embayment targeting areas of anomalous regional government survey (RGS) stream-sediment geochemistry in areas of prospective geology and structure. That work led to the identification of an area of gold anomalism flanking the eastern margin of the Border pluton, a Cretaceous granodiorite intruding deep water carbonate and siliciclastic rocks of the Misty Creek Embayment.

In 2018, work at Astro involved follow-up stream-sediment and soil sampling that outlined a ten-kilometre-long corridor of gold anomalism originating from a series of northwest-striking faults exposed along the range front. The faults offset sandstone, siltstone and lime mudstone intruded by the Border pluton and the smaller Mehitabel intrusion in Yukon. Prospecting along the corridor initially identified the Radio prospect, a magnetite-pyrite skarn horizon that returned 30m @17.7g/t gold in chip-channel samples, and the Microwave prospect, an exposure of silicified, gossanous sandstone that returned 11m @ 2.25g/t gold from chip-

channel samples. The 2018 program also outlined two other coherent gold-in-soil anomalies over areas of sparse outcrop and thin till cover along the range front and resulted in the designation of the Astro Project

This year, field work on the Astro Project included focussed mapping and sampling, hand trenching, an airborne geophysical survey and 11 reverse-circulation (RC) holes totalling 1111 metres. The results from this program continue to highlight a structural corridor of gold prospects extending for at least ten kilometres. The mapping program identified another gold-bearing skarn one kilometre southeast of Radio and gold-bearing quartz veins in siltstone west of Radio. The RC scout drilling program, in turn identified several new gold-bearing zones, including an interval of mineralized granodiorite east of Radio and silicified siltstone in a range-bounding fault at the Gamma prospect. Results to date display a zonation from gold-bismuth±copper showings in proximity to the Border pluton outward to gold-arsenic-antimony occurrences in siltstone and intrusive rocks along the range front.

DINÀGÀ WEK'ÈHODÌ; PROPOSED INDIGENOUS AND TERRITORIAL PROTECTED AREA

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Establishment of Dinàgà Wek'èhodì as a protected area is moving forward. The Tłıchọ Government, the Government of the Northwest Territories and other Indigenous Governments

are collaborating to achieve a shared vision for this culturally and ecologically significant area.

In 2007, Elders and representatives from the Tłı̨chǫ Government met with members of the federal and territorial government to express their interest in protecting several sites in the Tłı̨chǫ region, including the Dinàgà Wek'èhodì area. Elders developed a preliminary study area in 2008 for the candidate protected area – including the shoreline of the North Arm, K'ichì (Whitebeach Point), small islands and some water extending from the shoreline. A comprehensive, multi-stakeholder conservation planning process was initiated in 2010, to gather information on the cultural, economic and economic values of the area.

The establishment and management of Dinàgà Wek'èhodì will result in the protection, conservation and maintenance of biodiversity, ecological integrity and cultural continuity; it will promote reconciliation, advance government to government relationships, and contribute to economic diversification for the benefit of Indigenous peoples. It will create a foundation for growing sustainable and healthy communities through the pursuit of conservation economies. Future management of Dinàgà Wek'èhodì will incorporate climate change, human well-being, sustainable livelihoods and economic prosperity considerations based on the best science and traditional indigenous knowledge.

To advance the establishment of Dinàgà Wek'èhodì, the GNWT and the Tłı̨chǫ Government are leading the collaborative development of a management and monitoring framework in partnership with the Yellowknives Dene First Nation (YKDFN), Northwest Territory Métis Nation (NWTMN), North Slave Métis Alliance (NSMA) and the Wek'èezhìi Renewable Resource Board (WRRB). This framework will inform the establishment of Dinàgà Wek'èhodì and set the

stage for future management and monitoring.

Tłı̨chǫ Government has created a special zone in the Tłı̨chǫ Wenek'e (Tłı̨chǫ Land Use Plan) known as Dèk'easizedaà Wèhòqdia (Habitat Management Zone), which complements the future Dinàgà Wek'èhodì protected area. The shoreline of the North Arm of Great Slave Lake, within Tłı̨chǫ Lands, are protected under chapter 16 of the Tłı̨chǫ Agreement. Dinàgà Wek'èhodì as both an Indigenous protected area and future territorial protected area, covers an area of 750 km², adjacent to Tłı̨chǫ lands in Mòwhì Gogha Dè Nı̨tłèè, within the Wek'èezhìi Resource Management Area. The northeast and southwest boundaries are adjacent to Tłı̨chǫ settlement lands. The current Interim Land Withdrawal (ILW) is in place until October 2020.

ZIRCON TRACE ELEMENT AND HF ISOTOPIC COMPOSITION OF GRANITOID ROCKS IN THE EASTERN SELWYN BASIN, NORTHWEST TERRITORIES: A RECONNAISSANCE-SCALE STUDY

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Crustally derived intermediate to felsic plutons were emplaced across the eastern Selwyn Basin (SB) in the Northwest Territories within a post-accretionary tectonic setting from ~100-90 Ma. This magmatism is economically notable for the

association between world-class W skarn mineralization and the Tungsten plutonic suite in the region. Recent work has divided these plutons into several suites and sub-suites on the basis of U-Pb age, whole rock geochemistry and radiogenic isotopic composition, and demonstrated that the magmas were likely derived from intermediate-composition infracrustal rocks that are more isotopically evolved in the northeast SB (older \pm more felsic). The influence of magmas derived from supracrustal rocks and the mantle is also apparent; however, these melt sources are now interpreted to be less significant in the eastern SB than previously thought. Detailed compositional investigations of magmatic and inherited zircon can provide direct information on the age and composition of melt sources in the middle to lower crust underlying the eastern SB. A pilot study of trace element (TE) and Hf isotopic composition of zircon (magmatic rims and antecrystic cores) was conducted on samples from representative plutons in the eastern SB to test and better constrain earlier conclusions regarding magma petrogenesis. This study also included a limited examination of inherited zircon cores to further elucidate the age and composition of crustal melt sources.

Initial results generally support the earlier petrogenetic interpretations regarding the composition of magma source rocks, as well as the previously noted change in melt source composition from southeast to northeast. Zircon morphologies vary between plutonic suites, reflecting differing magma temperatures and alkalinity during precipitation. The range of TE compositions of magmatic zircon in the southeast is compositionally restricted and has a relative HREE-enrichment, whereas magmatic zircon from the northeast is more compositionally variable and LREE- and Th-enriched. TE contents and ratios (e.g., La, Ti, Yb/Gd, Lu/Hf) and ϵHf_{100} vary with plutonic suite and

geographically from southeast to northeast. In the southeast SB, magmatic zircon (rims and antecrystic cores) and inherited zircon all have similar Hf isotopic compositions, which are consistent with a relatively 'young' infracrustal melt source ($T_{\text{DM}} = 1.1\text{-}1.5$ Ga). In zircons from the northeast SB, Hf isotopic compositions of magmatic rims and antecrystic cores indicate the involvement of a slightly more evolved or older melt source ($T_{\text{DM}} = 1.4\text{-}1.8$ Ga), whereas inherited cores are significantly more isotopically evolved and consistent with the incorporation of zircons derived from much older rocks ($T_{\text{DM}} = 2.0\text{-}2.75$ Ga). Zircons from samples of the Tungsten plutonic suite in the southeast and northeast SB also display these regional variations. Although limited, these preliminary data complement previous interpretations but also provide new petrogenetic information on the plutonic suites and sub-suites that raises further questions and highlights the complexity of magmatism in the eastern SB. Additional work is needed to better define geographic and intra-/inter-suite variation in magmatic zircon composition, and systematic analysis of inherited zircon will better constrain the age and composition of the lower to mid-crustal melt sources.

SUMMARY OF FINDINGS FOR THE MARIAN WATERSHED STEWARDSHIP PROGRAM, 2013 TO 2019

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The Marian River drainage basin is a culturally and historically significant area to the TłichŦ people. To assist with the protection of aquatic resources in the drainage basin, the Marian Watershed Stewardship Program (MWSP) was created in September 2013. Directed by the TłichŦ Government Department of Culture and Lands Protection, the MWSP has included participation and support by the Wek'èezhì Land and Water Board, Wek'èezhì Renewable Resources Board, Fisheries and Oceans Canada, and Wilfrid Laurier University. The monitoring design is based on annual monitoring completed from a camp that rotates across four different areas of significance to the TłichŦ community: Marian Lake, Marian River, Hislop Lake, and Shoti Lake. The data is particularly relevant considering the construction of the TłichŦ All-Season Road to Whatì, which may soon lead to the development of the NICO Project and other major projects in the region. In addition to collecting baseline data, the monitoring program provides opportunities for training for youth and useful dialogue between scientists and traditional knowledge holders

on the status of the aquatic ecosystem. We present a brief overview of the aquatic studies completed to date, including a preliminary summary of fish tissue chemistry data collected on Lake Whitefish and Northern Pike populations.

CENTRAL MACKENZIE VALLEY BASIN ANALYSIS PROJECT – AN UPDATE

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Basin modelling is an important tool to understand the evolution of a sedimentary basin through time. The principal method for this type of analysis is numerical simulation with specialized software. A basin model requires multiple inputs, including but not limited to: stratigraphy, lithology, regional geology, tectonic history, and thermal flux. The Northwest Territories Geological Survey (NTGS) initiated a basin modelling project of the Central Mackenzie Valley (CMV) in order to model the Devonian sedimentary basin, and ultimately to refine the resource estimates for the unconventional hydrocarbon plays of the Horn River Group. In the last 15 years, the CMV has been the subject of multiple surface outcrop and subsurface well studies by both the NTGS and the Geological Survey of Canada. Nonetheless, it is understudied relative to hydrocarbon-producing areas in southern Canada. The regions included in this study are the Mackenzie Plain and adjacent portions of the Peel Plateau, Peel Plain, and Franklin Mountains.

The basin modelling project comprises several phases. The first phase is to identify available

public data and prepare them for import into Zetaware, the basin modelling package used by NTGS. Approximately 600 wells and 30 outcrops were in the initial dataset selection as inputs for this project. The data must go through a quality assurance before being imported into the software, which will reduce the ultimate total. The following step is setting up a 1-D model for each well or outcrop by entering multiple parameters into Zetaware's Genesis module. Parameters required for each 1-D model include the lithology (as a percentage composite of sub-lithologies), thickness, and depositional age (to the nearest million years) of each stratigraphic unit, erosion and hiatus events (based on past studies of regional geology and best available knowledge). If available, temperature measurements at depth (from drill-stem tests) and thermal maturity data (%Ro from vitrinite reflectance analysis) are also used in the model.

Future work includes integrating all of the 1-D models into a regional 3-D framework in Zetaware's Trinity module using surfaces based on recently interpreted seismic data. The following step is to include Zetaware's Kinex module to model of hydrocarbon generation and expulsion from known source rocks based on real world analytical results. The final integrated 3-D model would then be iteratively tested against current known conditions in the basin for accuracy. A sufficiently accurate model could then be used to understand the evolution of the basin, the development of known hydrocarbon systems, and potentially predict the existence of previously undiscovered resources. This talk will highlight the initial data input steps and creation of 1-D models in Genesis, and give a brief glimpse of future steps in the modelling project.

TRENDS IN SOCIO-ECONOMIC IMPACT ASSESSMENT AND INDIGENOUS ENGAGEMENT IN THE NWT

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Twenty years ago, socio-economic impact assessment (SEIA) was almost an afterthought in Environmental Impact Assessment (EIA) in the Northwest Territories (NWT), but it has evolved and now carries far more weight in planning, making decisions and implementing projects than it used to. The meaningful participation and support of Indigenous communities in EIA and other aspects of the integrated resource management system are essential for success in the regulatory process for any project. Socio-economic impact assessment and Indigenous engagement are of at least the same importance as the biophysical environment, technical and fiscal considerations. While currently, the NWT is experiencing a slow period in the resource development cycle, there is an opportunity to critically examine the collective experience and improve practices related to engagement, and the assessment and mitigation of social, cultural and economic impacts.

There has been extensive experience in the NWT by various parties involved in resource development. These include communities, governments (Indigenous, Territorial, Federal), regulators, proponents, the public, and non-government organizations. This experience covers not only the SIEA and Indigenous engagement aspects of EIA, but also project construction, operation, and decommissioning. EIAs have been completed for many resource development proposals, (both mineral

development and oil and gas), with an approach that considers the environment, including the social, economic and cultural well-being of people in the NWT.

There have been 'lessons learned' and an evolution of expectations and practices. What do these experiences and trends in SEIA and Indigenous engagement offer in terms of successful outcomes? What are the key factors and implications going forward? This presentation will look at the evolving importance of SEIA and Indigenous engagement in the resource development sector.

CHARACTERIZATION OF APATITE WITHIN THE MACTUNG W (CU, AU) SKARN DEPOSIT, NORTHWEST TERRITORIES: IMPLICATION FOR THE EVOLUTION OF SKARN FLUIDS

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The Mactung W (Cu, Au) deposit, Northwest Territories, is a scheelite-rich, calc-silicate exoskarn located at MacMillan Pass, Selwyn Basin. Cretaceous magmatism and associated

granitic intrusions led to ore development in two distinct packages of Cambrian to Silurian-aged limestone interbedded with pelite, referred to as the upper (units 3D-F) and lower (unit 2B) ore zones. Apatite is an accessory mineral occurring at Mactung, which accommodates a variety of trace elements within its crystal structure thereby recording the chemical evolution of fluids in geological systems. Multiple generations of skarn-hosted apatite from Mactung were characterized in order to understand the skarn paragenesis, chemical evolution and signatures of mineralizing fluids. Petrography and rare-earth element (REE) abundances constrain four generations of fluorapatite, that each recorded distinct chemical stages in the evolution of the skarn system. *Type-i* apatite occurs with detrital phosphate nodules. This apatite contains variable $\Sigma\text{REE}+\text{Y}$ (1314 ± 821 ppm, 1σ , $n = 78$) and has negatively-sloping chondrite-normalized REE+Y ($\text{REE}+\text{Y}_\text{N}$) patterns with variable $\text{LREE}_\text{N}/\text{HREE}_\text{N}$ ($\text{La}_\text{N}/\text{Lu}_\text{N} = 27 \pm 30$) and weak Eu anomalies ($\text{Eu}_\text{N}/\text{Eu}_\text{N}^* = 0.6 \pm 0.2$; $\text{Eu}^* = \sqrt{\text{Sm}_\text{N} \cdot \text{Gd}_\text{N}}$). The REE abundance in *type-i* apatite is similar to that of the phosphate nodules, and both have similar REE abundances as in phosphate nodules reported in unaltered Devonian-aged calcareous mudstone of Howards Pass, Selwyn Basin. The similarities in REE suggest that *type-i* apatite is a recrystallization product of phosphate nodules, likely during isochemical contact metamorphism. *Type-ii* apatite occurs in anhydrous prograde skarns and show high abundances of REE, and flat lying REE+Y_N patterns (e.g., $\Sigma\text{REE}+\text{Y} = 17194$ ppm; $\text{La}_\text{N}/\text{Lu}_\text{N} = 3.5$; $n = 31$) with negative Eu anomalies (e.g., $\text{Eu}_\text{N}/\text{Eu}_\text{N}^* = 0.1$). Hydrothermal *type-iii* apatite is associated with quartz-scheelite veins, which cross-cut prograde skarn. This apatite contains very high $\Sigma\text{REE}+\text{Y}$ (7752 ± 496 ppm, $n = 3$) and exhibit bowl-shaped REE+Y_N patterns, corresponding to low MREE ($\text{La}_\text{N}/\text{Sm}_\text{N} = 8 \pm 0.3$; $\text{Sm}_\text{N}/\text{Lu}_\text{N} = 0.3$), and no Eu anomaly. Lastly, *type-iv* apatite is hosted in hydrous retrograde skarns

and shows bowl-shaped to negatively sloped REE+Y_N patterns, characterized by low MREE content (e.g., La_N/Sm_N = 10.2; Sm_N/Lu_N = 0.3; n = 17) and positive Eu anomalies (e.g., Eu_N/Eu_N* = 14.3). The paragenesis and distinct REE+Y_N patterns of hydrothermal *type-ii*, *type-iii* and *type-iv* apatite are explained by the presence of two chemically distinct ore fluids during the different stages of mineralization. The first fluid formed *type-ii* apatite, prograde skarn and early, fine-grained scheelite. The second fluid was associated with late-stage quartz veining, retrograde skarn, and coarse-grained scheelite. The REE+Y_N patterns of *type-iii* and *type-iv* apatite record a second fluid that underwent MREE fractionation either through crystallization of these apatites, or during the partial dissolution and remobilization of earlier scheelite. Preliminary cathodoluminescence images and trace element data from coeval scheelite show evidence for two generations of scheelite with distinct REE signatures, supporting the interpretation of two ore fluids. The trace element compositions of scheelite, and radiometric ages of scheelite and apatite, are currently being investigated to further constrain the chemical evolution and paragenesis of these two ore fluids.

MULTI-SCALE INVESTIGATIONS TO MAP PERMAFROST LANDSCAPE CHANGE

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Arctic landscapes are in a period of transition, where increasing temperatures and changing precipitation regimes are intensifying disturbances associated with permafrost degradation. A framework for determining the susceptibility of the landscape to thermokarst would allow us to understand the future of circumpolar landscapes better. One approach to examine thermokarst susceptibility is with geospatial analyses and statistical models. These models are developed to represent the susceptibility of an area given the current distribution of climate, topographic and material conditions, with an understanding that these conditions likely influenced past thermokarst. Through the model, spatial patterns of thermokarst can be investigated in relation to specific geophysical variables (i.e., glacial history, slope, permafrost characteristics, surficial geology, etc.) and, in return, relevant information on relationships between terrain variables and thermokarst can be explored. Modelling results are presented as probabilities, with areas on the landscape identified as being more or less susceptible to thermokarst. While many of these models are trained with point-

based data, the ability to move from point-based measurements to spatially distributed assessments of factors contributing to thermokarst is essential for forming a generalizable understanding of both earth-system processes and the interaction between natural systems. This presentation will highlight: 1) thermokarst susceptibility modelling trained with thermokarst inventories at different scales (i.e. field-based mapping and inventories developed using fine and coarse resolution imagery); 2) explore the physical factors driving the alteration of thermokarst systems and how they are represented at different scales; 3) examine how results of these models can inform risk assessments and decision making to improve public safety and environmental management.

NUNAVUT MINERAL EXPLORATION AND MINING OVERVIEW 2019

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In 2019, Nunavut saw the continued shift from primarily early exploration-stage to advanced-stage exploration and mine development projects. In addition to Baffinland's Mary River iron mine, the territory currently has three operating gold mines: Agnico Eagle's Meliadine, which commenced commercial production in May, and TMAC Resources' Doris. With production from the third gold mine, Agnico Eagle's Meadowbank, ceasing in Q3 of 2019, the company is bringing the Whale Tail deposit at Amaruq into production later this year.

According to statistics released by Natural Resources Canada, spending intentions for mineral exploration and deposit appraisal have steadily declined over the last four years to \$144 million in 2019, down from almost \$150 million in 2018. This places Nunavut fifth in Canada for mineral exploration spending. As in previous years, exploration for gold accounts for the bulk of that total, with lesser amounts spent on base metals, diamonds, and iron. Major companies were expected to spend nearly twice as much on exploration and deposit appraisal as junior exploration companies in Nunavut. With Whale Tail (Agnico) and Madrid North Naartok East deposits (TMAC) approaching commercial production, Nunavut has also seen an increase in mine complex development and capital assets spending.

Significant advances were made at Sabina Gold and Silver Corp.'s Back River gold project with the construction of a winter ice road between the marine landing area and the Goose deposit, and with continued exploration and definition drilling programs following the 2018 discovery of the Nuvuyak zone as well as other encouraging results from Llama, Umwelt, and Goose Main deposits. TMAC's Hope Bay gold project saw development and exploration activities, with underground definition and exploration drilling at Doris BTD zone and surface exploration drilling at Doris Valley to the north of the Doris deposit, and at the Boston and Madrid North deposits. The company is also planning to commence processing ore from its Madrid North Naartok East crown pillar in Q3 of 2019. Other active gold explorers in Nunavut this year included Nordgold (Pistol Bay), Canarc (Hard Cash), Auryn Resources (Committee Bay), Solstice Gold (Kahuna Gold), Blue Star Gold Corp. (Hood River), and Margaret Lake Diamonds (Kiyuk Lake).

Two companies were actively exploring for diamonds in Nunavut in 2019. De Beers Canada Inc. purchased Peregrine Diamonds Ltd. last

year, acquiring the Chidliak diamond project and several other projects in Nunavut and Northwest Territories. The company plans to construct an innovative mine on the property with limited footprint, environmental impact and powered by clean energy. GGL Resources Corporation conducted a ground geophysical survey on the Stein property located on Boothia Peninsula, identifying a number of promising anomalies.

With the opening of new mines and continuous investment in early and advanced stage active exploration projects, Nunavut is continuing to prove its mineral potential.

IMPROVING EXPLORATION SUCCESS IN NORTHWEST TERRITORIES WITH REGIONAL SURFICIAL MAPPING PRODUCTS AND OVERCOMING THE CHALLENGES IN PROVIDING HIGH-QUALITY INFORMATION IN VAST AND REMOTE REGIONS

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The Northwest Territories has significant potential for economic mineralization. Diamond, gold, volcanogenic massive sulphide, tungsten, lead-zinc, cobalt and rare earth mineralization has been identified across the

region. The vastness and remoteness complicate field practices and necessitate exploration methods that are scalable, cost-effective and can detect mineralization at a range of distances. As such, drift prospecting has been a fundamental method in mineral exploration for many years and led to a large proportion of the mineral discoveries in the region. Subglacial till is the optimal sample medium for drift prospecting because it has the nearest composition to bedrock of all sediments, it is common across the landscape, it has a relatively simple transport history, and it can produce detectable anomalies that are many square kilometres in extent. As many of these discoveries have shown, drift prospecting using subglacial till can point an arrow to mineralization. The arrow, however, can become significantly obscured where the surficial geology is complex or subglacial till has been modified or remobilized by post-depositional processes such as glacial meltwater or cryoturbation. Resulting changes to geochemical and mineralogical concentrations or distribution reshape primary dispersal patterns resulting in anything from smeared dispersals to discontinuous anomaly clusters with no indicated source. As discoveries continue in ideal settings, less attention is given to the more complex areas with similar or better mineral potential. To help exploration companies unravel the complexities in the surficial geology, the Northwest Territories Geological Survey has initiated regional surficial geology mapping programs specifically tailored to exploration throughout NTS map sheets 075M/N, 076C/D/E/F and 086H. These products provide a comprehensive surficial framework that informs exploration practices, and derivative products designed to improve success by identifying what map units are well to poorly suited for till sampling. This presentation will demonstrate how the surficial geology and till sampling suitability mapping can be used to plan and execute more streamlined till sampling programs, determine the utility of existing data and optimize

evaluation methods. In addition, we will discuss the approaches used to overcome the challenges of producing detailed, high-quality products in vast and remote regions under aggressive timelines. These components culminate in improved data collection and program efficiency, higher quality data and suitable evaluation methods and a reduction in the risks and costs associated with exploration in remote regions.

THE RELATIVE TIMING OF REGIONAL SHORTENING AND PLUTON EMPLACEMENT IN THE SOUTHEASTERN SELWYN BASIN, CANTUNG, NT

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Early Jurassic to mid-Cretaceous accretion of the Yukon-Tanana terrane on the margin of ancestral North America resulted in the formation of eastward propagating compression that generated extensive folding and thrusting – the Cordilleran Orogeny. Between the orogenic core and foreland fold-and-thrust of the Mackenzie platform lies the Selwyn Basin, a slope-to-basin facies strata that represents passive margin sedimentation from the Neoproterozoic to the Paleozoic. Selwyn Basin rocks are intruded by 98-89 Ma Tombstone-Tungsten Belt (TTB) intrusions. In the northern Selwyn Basin, TTB intrusions cut ductile deformation fabrics and are considered

post-tectonic, with crustal shortening in the northern Selwyn Basin ending before 98 Ma. Cooling ages of mica from thrust faults indicate that deformation had probably ended by about 100 Ma. In the central Selwyn Basin, undeformed ~98-97 Ma South Fork volcanics also suggest deformation had stopped there by a similar time.

TTB intrusive belt in the southeast Selwyn basin is dominated by 99 to 95Ma Tay River suite and 98 to 94 Ma Tungsten suite. The latter intrusions are associated with significant W mineralization, including the world-class Cantung W-Cu-Au skarn, which formed above the 98 Ma Mine Stock. There has been limited detailed analysis of the relative timing of deformation to the emplacement of Tungsten suite plutons and skarn formation in the Cantung region. Here we present results of an analysis of the timing of regional deformation relative to pluton emplacement using a combination of regional fold and foliation geometry, overprinting foliation patterns, and porphyroblast-matrix microstructural relationships.

Early Cambrian to Mississippian strata in the Cantung region form a NW-SE trending upright fold train, F1, and corresponding axial planar foliation, S1; the product of NE-SW crustal shortening. In the Cantung region, F1 folds above Tungsten Suite intrusions, including the mine stock, are more open with a lower amplitude to wavelength ratio than in the areas between the stocks. The geometry indicates that plutons were emplaced during the formation of F1 folds and that shortening continued post-emplacement.

A variably-developed crenulation cleavage, S2, is well-developed in the thermal aureoles of Tungsten suite plutons and developed synchronously with cordierite and andalusite porphyroblasts that overgrow and preserve S1 as inclusion trails. S2 is less well-developed

outside contact aureoles. Regionally, S2 has a sub-horizontal to shallowly inclined orientation. Above the Mine Stock, F1 folds are rotated to a shallower dip and this is attributed to vertical shortening in the thermal aureole. The same shortening is responsible for the formation of S2. Locally, S2 is crenulated by a sub-vertical S3 foliation. S1 and S3 are geometrically indistinguishable from each other and represent a continuum of NE-SW shortening that was only locally interrupted by periods of vertical shortening in the thermal aureoles of the intrusions.

Data collected in this study indicates that the emplacement of Tungsten suite plutons at Cantung occurred during regional NE-SW shortening and are not post-tectonic as previously considered. Rather deformation in the SE Selwyn Basin continued after deformation had ceased further to the west, highlighting the diachronous nature of the Cordilleran orogeny.

TRANSPORTATION CORRIDORS AND ACCESS TO RESOURCES IN THE NORTHWEST TERRITORIES

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In a largely greenfield region like the Northwest Territories, there are opportunities to plan new infrastructure projects with resource potential firmly in mind.

Under the GNWT Department of Infrastructure's (INF) Transportation Strategy, INF is advancing the planning for three

transportation corridors: the Tłı̨chǫ All-season Road, the Slave Geological Province (SGP) Corridor, and the Mackenzie Valley Highway.

The SGP is a region of high mineral potential and is host to the NWT's diamond mines and most of the NWT's past producing gold mines. The SGP has the potential to sustain the NWT mineral development cycle for decades to come. The current route being considered was informed by mineral potential mapping to guide the planning to maximize the potential for future resource projects. With recent funding investments by the federal government and the GNWT, work is progressing on all three of these strategic infrastructure projects.

This talk provides an overview of these transportation infrastructure initiatives, highlighting the role of mineral potential mapping in scoping of the SGP Corridor route.

TERRAX MINERALS INC. YELLOWKNIFE CITY GOLD PROJECT - DRILLING UPDATE

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During 2019 TerraX completed 5,601 metres of diamond drilling in 22 NQ drill holes. The majority of this drilling was completed on the Sam Otto South, 9 holes totaling 1914 metres, and Crestaurum, 9 holes totaling 2719 metres, targets. The remainder of the drilling was completed on the Berry Hill and Ryan Lake

targets. Gold assays are still pending for all drill holes except the initial six (6) holes drilled on the Sam Otto South target.

The 1182 metres in the first six (6) holes drilled on the Sam Otto South zone indicate that continuous zones of gold mineralization occur along the 1200 metre strike length and remains open in all directions. This zone was first intersected by three 400 to 500 metre spaced drill holes in 2018. The 2019 drill holes were spaced 100 to 150 metres apart. With these results the gold mineralization has been defined for a minimum of 2.5 kilometres along the five (5) kilometre Sam Otto structural corridor. The drill assay highlights from the 2019 drilling are: 2.93 g/t Au over 7.00 m in hole TSO19-043; 1.36 g/t Au over 14.00 m in hole TSO19-046; 1.24 g/t Au over 11.00 m in hole TSO19-047; 2.10 g/t Au over 4.00 m in hole TSO19-047; and 7.43 g/t Au over 1.00 m in hole TSO19-047.

The Crestaurum Zone drilling totaled 2719 metres in 9 holes. All holes hit the Main Zone, and multiple Hanging-wall zones were also intersected. Assay results are pending.

The two holes totaling 230 metres drilled on the Ryan Lake target intersected multiple veins with pyrite, chalcopyrite and molybdenite mineralization. Assay results are pending.

The two holes totaling 737 metres drilled on the Berry Hill target intersected well developed ankerite alteration and moderately developed pyrite mineralization. Assay results are pending.

TERRAX MINERALS INC. YELLOWKNIFE CITY GOLD PROJECT - BANTING GROUP VERSUS KAM GROUP GOLD MINERALIZATION

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Mapping completed by TerraX during 2014-2019 has built on the historic mapping in the Kam and Banting Group's. This work has further outlined gold mineralization hosted in the Banting Group, which hosts the Sam Otto style, and Kam Group, which is host to the Giant, Con and Campbell shear zone styles.

The Sam Otto style mineralization has been defined for about 2.5 kilometres along the five (5) kilometre Sam Otto north-south trending (i.e., 000 to 005/75) structural corridor. Within this corridor there are 100 to 200 metre wide, moderate to strongly developed shear zones hosted within an intermediate crystal tuff. Locally higher-grade lenses occur which are at a 10 to 15 degree angle to the main north-south shear. Alteration changes from distal biotite-chlorite to proximal silica and sericite associated with the gold mineralization. Sulphide mineralization (i.e., pyrite, pyrrhotite and arsenopyrite) associated with the gold appears to be related to the sulphidization of very fine-grained primary magnetite that is spatially associated with biotite-chlorite aggregates. This feature is best defined by changes in magnetic susceptibility with changes from $>1.0 \times 10^{-3}$ SI units in unmineralized zones to typically 0.1×10^{-3} to 0.6×10^{-3} SI units in gold

bearing zones. The highest-grade gold mineralization is associated with well-developed silica-sericite alteration, acicular arsenopyrite, fine grained pyrite/pyrrhotite and S2 parallel (010-015/80) quartz veins.

The 2019 mapping on the extension of the Giant mine geology outlined a folded and strongly sheared and altered package of mafic flows, intermediate to felsic tuffs, porphyry dikes and gabbro dikes and sills. In addition, the Bode fragmental unit was outlined 250 to 500 metres west of the Jackson Lake Formation unconformity. This suggests a structural and stratigraphic setting similar to that of the Campbell Shear.

DUST IN THE WIND: VEGETATION, SOILS AND DUST DEPOSITION MONITORING AT THE GAHCHO KUÉ MINE

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A vegetation and soils monitoring program was implemented at the Gahcho Kué Mine to test for mine-related changes to vegetation and soils from dust deposition. Besides measuring changes in vegetation and soils, one objective of the study is to inform the Wildlife Effects Monitoring Program with respect to the potential for dust as a mechanism for avoidance of habitats near the Mine by caribou and other wildlife.

Soil properties, plant communities, and dust deposition have been monitored since 2013 with permanent vegetation plots and dust collectors using a gradient study design prior to and during construction and operation of the Mine. A single study area transect was established in a west-southwest direction extending 20 kilometres from the Mine footprint, which was based on the prevailing wind direction and terrain features (i.e., large lakes), and the distribution of the target plant community across the landscape.

Dustfall deposition and associated metals concentrations, and soil moisture and temperature variables are monitored annually. Data on plant species richness and abundance and soil pH and salinity are collected every three years. Analysis of variance was performed to determine if fixed dustfall deposition rates varied among sampling areas, seasons, and years. A repeated measures analysis of variance was used to examine patterns of species abundance (percent cover) and species richness across sampling areas and years.

Although dust deposition has shown increasing trends since the commencement of construction and operation, no effects on vegetation from dust were observed in the current analysis. Metals concentrations in dust were generally below detection limits or in trace amounts, consistent with baseline values, and soil pH and salinity were within baseline values. Minor observed changes in species richness are likely related to natural variation in site conditions among vegetation plots and associated sampling areas, annual variation in climate, surveyor variability, and foraging by caribou and other wildlife. Differences in annual dust deposition rates may be attributed to annual variations in temperature, wind, and rainfall. The results suggest that dust-related changes in vegetation community composition is likely not a factor influencing the avoidance of habitats near the Mine by caribou or other wildlife.

ACCOUNTING FOR HABITAT DISTRIBUTION IN CARIBOU ZONE OF INFLUENCE: A NEW ESTIMATION USING GENERALIZED ADDITIVE MIXED MODELLING METHODS

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Barren-ground caribou are a culturally and ecologically important species in Northern Canada. Recent population estimates suggest that the barren-ground Bathurst caribou herd, has declined by as much as 98% from peak numbers experienced in the 1980s and early 1990s. Research elsewhere in Canada and in Scandinavia on other caribou and reindeer populations, together with Traditional Knowledge in the North indicates that caribou may avoid certain anthropogenic activities, leading to theories that barren-ground caribou may respond to industrial development by changing their distribution. The term “Zone of Influence (ZOI)”, was coined to refer to the distance at which caribou change their behaviour, habitat selection and distribution relative to an anthropogenic disturbance (e.g., a mine or road).

In 2012, Boulanger et al. published a first analysis using aerial survey data to determine if Bathurst caribou were avoiding the Ekati-Diavik mine complex, situated within the herd's summer range, in a ZOI. The authors reported an 11-14 km ZOI surrounding mine infrastructure and hypothesized fugitive dust from the mine complex to be a possible mechanism for this ZOI. Subsequently, a 14 km ZOI around active mines has been assumed by land managers; however, the underlying mechanisms influencing the size of ZOI remain poorly understood.

The current study re-examined the ZOI at the Ekati-Diavik mine complex using an alternative analysis approach that incorporated two major differences from the Boulanger et al. 2012 estimation of ZOI:

1. the underlying assumption that caribou distribution occurs in a complex, non-linear fashion, particularly in areas of higher quality habitat (i.e., heath tundra), as determined by Resource Selection Function studies conducted in the Ekati-Diavik mine complex.
2. the use of a flexible spline model for distance that allowed for an unequal distribution of occupancy that is not accounted for by habitat alone, rather than a piecewise linear model. The current model predicted caribou occurrence peaks at several distances from the mine complex: 8 km, 16 km, and 27 km. Statistical analysis of the results showed that the base habitat model is the primary control (an Area Under the Curve of 0.7897); when distance to infrastructure was added to the model, the model fit was not significantly improved (i.e., an increased AUC score of only 0.0056). This suggests that the distribution of caribou at the mine complex can be accounted for by

habitat variables rather than a mine-related ZOI.

It is hypothesized that previous studies on ZOI at Ekati-Diavik identified a ZOI because the authors used straight line fits that constrained the log odds occurrence of caribou to be linear with distance from infrastructure and interpreted the natural variation in the distribution of caribou and the relationship with better quality habitat as a meaningful ZOI. This study demonstrates that the underlying nature of habitat quality and caribou occurrence needs to be carefully considered when examining caribou habitat use. It is recommended that land managers consider using ZOI models that allow the distance effect to differ across direction from human disturbances or alternatively, use a 3D spatial approach.

THE CANADIAN CENTRE FOR CLIMATE SERVICES, A NEW RESOURCE TO SUPPORT NORTHERN CLIMATE CHANGE DECISION MAKING

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The Canadian Centre for Climate Services (CCCS) is a new dedicated service established

by Environment and Climate Change Canada (ECCC) so that Canadians have the information and support they need to understand and reduce risks from climate change. CCCS offers reliable climate information, data, and tools, and provides user support to help advance climate resilience across Canada. User support and training are among our key offerings, including a national support desk. CCCS supports a continuum of climate data portals suitable for a diverse set of users. Portals in the suite include the Climate Atlas of Canada, Climatedata.ca and PAVICS. CCCS is working to address northern climate services needs and unique challenges. To increase access to northern climate services, CCCS has based staff in the north, is assisting northern clients, undertaking needs assessments, inventorying available products, conducting outreach, and developing projects to enhance northern climate products. CCCS is working with Territorial governments and others to explore options to enhance northern capacity through a potential northern climate services organization.

EVALUATION OF THRESHOLD FREEZING CONDITIONS FOR WINTER ROAD CONSTRUCTION OVER DISCONTINUOUS PERMAFROST PEATLANDS, SUBARCTIC CANADIAN SHIELD

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Winter roads are important transportation corridors in northern regions. The Tibbitt to Contwoyto Winter Road (TCWR) traverses the subarctic Canadian Shield and is the most heavily used winter road in Canada. In addition to lake-ice thickness, trafficability on the TCWR depends on adequate freezeback of overland portages, which primarily traverse peatlands underlain by discontinuous permafrost. We investigate threshold requirements for the initiation of winter road operation and assess the use of a recommended 305 °C-day air-freezing index (FDD_{305a}) value to predict ground freezing at 30-cm depth, the standard depth for initiating winter road construction. Snow compaction and flooding enhanced freezeback of portages and early winter overland water flow had a similar effect. The majority of winter road portages were not frozen to a depth of 30 cm by FDD_{305a}. The results indicate that an FDD_a threshold of 1100 °C-days is more appropriate for drained and wet peatlands in this discontinuous permafrost environment. However, TCWR winter road operators presently plan the construction of the winter road by calendar date rather than by evaluation of the air-freezing index. This practice results in a conservative approach to the start of the construction season, close to 1100 °C-days, when a higher percentage of sites are frozen to 30-cm depth than would be if FDD_{305a} was used. In addition, the use of low-pressure vehicles for snow compaction during the start of the construction season is an effective adaptation practice to speed up ground freezing.

EVIDENCE FOR SULFUR SATURATION FROM ZIRCON-HOSTED MELT INCLUSIONS IN FELSIC PLUTONS AND DIKES OF THE YELLOWKNIFE GREENSTONE BELT, NWT

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The Yellowknife greenstone belt (YGB) is located in the Archean Slave province and consists of mafic and felsic metavolcanic sequences deposited between 2722-2701 Ma. The YGB is crosscut by at least three generations of porphyritic, feldspar-quartz and quartz-feldspar dikes (FQP and QFP). The belt was also intruded by several plutonic bodies that were emplaced episodically between 2675-2608 Ma and range from tonalite to granite in composition. These include the Ryan Lake pluton (2675 Ma), Defeat Suite (2630 Ma), and the Duckfish Granite (2608 Ma). The YGB hosts two historic high-grade, shear zone-hosted gold mines, the Giant and Con mines which produced a total of 14.2 Moz gold. Throughout the YGB, gold mineralization is spatially associated with FQP and QFP dikes and has been documented in shear-zones that crosscut other plutonic bodies. However, it is poorly understood whether this association is purely spatial or if a genetic connection exists between the anomalous precious metal concentrations and felsic intrusions. Qualitative melt inclusion data was collected to evaluate the mineralization potential of these intrusions.

Melt inclusions represent a sample of magma trapped in a growing crystal during fractionation and crystallization of a rock. They can provide a snapshot of information related to magma sources, pre-existing metal endowment, and pressure and temperature conditions during entrapment. Due to their robust nature and prevalence in the lithologies of interest, zircons were the prime candidate for analysis. Zircons from mineral separates were obtained, mounted in epoxy and polished until the melt inclusions were exposed or close to the surface. LA-ICP-MS analysis was conducted for major, minor, and trace element data for zircon-hosted melt inclusions. Ablations targeted spherical and ovoid, opaque inclusions while attempting to avoid any obvious cracks or mineral inclusions. Although the data obtained is qualitative, many ablations of dark brown-black inclusions were found to be sulfur-rich, likely due to the presence of sulfide melts. These sulfide inclusions were also enriched in Cu, As, Sb, and Pb. This data suggests that sulfur saturation was achieved at the time the inclusions were trapped. Therefore, gold mineralization may be genetically associated with the felsic plutons and dikes as intrusion-related gold mineralization.

TALTSON HYDRO EXPANSION PROJECT

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The GNWT's 2030 Energy Strategy has identified the Taltson Hydroelectricity Expansion project as a key priority. This talk will provide an overview of the project, and highlight how the 60 MW Taltson Expansion

and interconnection into Yellowknife can provide a greener future for the territory's resource sector, stabilize the cost of energy for residents and set the stage for a full service infrastructure corridor concept (transportation, energy, and communications) that would provide clean hydroelectricity to the mineral-rich Slave Geological Province.

BEDROCK TOPOGRAPHIC AND TILL THICKNESS CONTROLS ON CONTRASTING TILL DISPERSAL PATTERNS FROM KIMBERLITES, SOUTHEAST OF LAC DE GRAS, NORTHWEST TERRITORIES

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Till dispersal patterns may appear as a consistent train of indicators extending in the direction of the latest ice-flow phase from a source, or along a direction defined by an older ice-flow phase. However, other dispersal patterns, sometimes even in the same area, may have poorly-defined, discontinuous trains, or even lack dispersal trains all together. This research investigates dispersal patterns from two sites southeast of Lac de Gras that were affected by the same ice-flow history, but show important differences in bedrock topography,

till thickness, and subglacial landform assemblages. The goal is to improve our understanding of bedrock and till thickness effects on dispersal trains.

New local ice-flow indicators (n=16) constrain local ice-flow history. Digital elevation models and a surficial map are used to identify surficial landforms and to loosely constrain bedrock topography. We also use a subset of KIM results from a large industry-donated RC-drilling database (n=502 from 185 boreholes) which includes information on subsurface sediment characteristics and depth-to-bedrock data, which further constrain bedrock topography. In addition, we use texture, matrix geochemistry, KIMs, and clast lithology from a smaller set of 51 surface samples to compare dispersal patterns at surface and at depth. Part of the eastern study area is characterized by a well-defined drumlin field associated with the young NW ice-flow phase, variable till thickness (0-18m), and relatively flat bedrock topography (<20m elevation change). Kimberlites WO-17/WO-20 exhibit a short, but well-defined KIM dispersal train in the direction of the last dominant flow phase (NW); the dispersal area is also characterized by thin discontinuous till. A second KIM dispersal train is also recognized in the thicker till of the drumlin field SW of WO-17/20. Based on its location relative to WO-17/20, and till geochemistry and lithology counts, this pattern is interpreted to be a palimpsest train associated to the oldest SW ice flow. The western study area, located 20km from the eastern area, is characterized by a similar ice-flow history, but its bedrock topography varies more (~70m), with thin till, generally under 4m. A known kimberlite within the western area (Big Blue) is nestled within a bedrock topographic high ~20m above the surrounding terrain. Fragmented and more elusive till anomalies occur down-ice from this source. The lack of a well-developed dispersal train associated with the kimberlite is

noteworthy, and may be due to the evolution of subglacial conditions around the bedrock hill. Our current model involves initial basal sliding and erosion of the top of the kimberlite and englacial entrainment. This phase was followed by reduced local abrasion and erosion rates within the kimberlite depression, possibly related to the development of low-pressure cavities over several local depressions: an idea supported by evidence of late-stage meltwater activity. This research highlights the important role of bedrock topography and related subglacial conditions both in the source area and dispersal area, as well as the potential for enhanced preservation of palimpsest trains in drumlinized till blankets.

DIAVIK DIAMOND MINE A21 OREBODY

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Diavik's newest orebody, the A21 kimberlite pipe, was brought into production in December 2017 when surface mining began. This is the fourth kimberlite pipe to be mined at the Diavik Diamond Mine, located at Lac de Gras, 300 kilometres northeast of Yellowknife. To access this underwater orebody, Diavik constructed an engineered, 2.1 km long rock fill water retention dike during 2014 to 2017. This has now opened up the opportunity to study and evaluate possible mining methods below the open pit. Such additional kimberlite extraction would occur from 2023 to 2025.

DEVONIAN SHALE BASIN CHARACTERIZATION IN THE CENTRAL NORTHWEST TERRITORIES – RESULTS OF OUTCROP SAMPLING

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In 2014, the Northwest Territories Geological Survey (NTGS) continued the source-rock characterization studies of Devonian black shales, including the Bluefish Member of the Hare Indian Formation and the Canol Formation. As part of the ongoing Shale Basin Evolution Project, the NTGS sampled six outcrops during the summers of 2016 and 2018 – which in a southeast-northwest transect include Carcajou River, Dodo Canyon, Powell Creek, Arctic Red River East, Rumbly Creek, and Flyaway Creek. The study included strategically selected outcrops and stratal intervals in order to fill areal and stratal data gaps in the regional dataset. This work resulted in the creation of a detailed regional dataset covering the Devonian Horn River Group in the Central Mackenzie Valley and southern Peel Plain and Peel Plateau areas of the Northwest Territories (NWT). Here, the scientific results from the 2016 and 2018 summer field seasons are highlighted. These data, then, are combined with legacy data from several outcrops and industry cores and put into regional context.

The data suggest that the Bluefish Member comprises organic-rich shales with generally good, but regionally variable total organic carbon (TOC) content, also indicated by

consistently high uranium concentration. Silica content in the Bluefish Member is moderate and variable, resulting in lower brittleness of the rock, which was also observed in the field. Terrestrial input, based on geochemical indicators, is generally low for the Bluefish Member, but increases upward in stratigraphy. Palaeoredox indicators suggest deposition under at least partly anoxic conditions. The Bell Creek member has generally low TOC content and low uranium concentration. Silica content is also low with an elevated terrestrial input signature. Palaeoredox indicators suggest sustained oxic conditions. The Canol Formation has a variable but generally elevated TOC content. Silica content in the Canol Formation is the highest of these formations, resulting in brittle fracturing noted in the field. Terrigenous input is low through Canol Formation deposition. Palaeoredox indicators suggest variable conditions during deposition.

Source-rock and vitrinite reflectance analyses indicate a regionally variable trend of rock maturity, with an abrupt increase in maturity toward the western part of the study area. In the eastern locations (Carcajou River, Dodo Canyon, and Powell Creek), production index (PI), vitrinite reflectance (VR) and T_{max} values are in agreement, indicating maturity in the oil window. In the western outcrops, however, PI and T_{max} values are not in agreement; PI values indicate oil window maturity, whereas T_{max} values indicate overmaturity. The VR for these outcrops resulted in poor data quality. This trend in the western locations may be the result of expulsion and pyrolyzation of inert residual carbon.

Conodont and stable isotope analysis results from Arctic Red River East are complimentary and are used to elucidate the chronostratigraphy of these strata. The results are correlated to the global $\delta^{13}C_{carb}$ reference curve and conodont biozones, resulting in a high-resolution chronostratigraphic framework for the Horn

River Group at this location. Collectively, these results will be used in the on-going basin modelling efforts of the NTGS.

REVISITING THE IMPERIAL FORMATION – PALAEOENVIRONMENTAL RECONSTRUCTION AND POTENTIAL HYDROCARBON PLAY

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The Late Devonian Imperial Formation overlies the carbonates and shales of the Horn River Group, which have been the target of conventional and unconventional oil and gas exploration and development in the Northwest Territories (NWT) for approximately 100 years. The Imperial Formation, however, has to date been comparatively understudied, with the latest research on the formation conducted by the Northwest Territories Geoscience Office – now the Northwest Territories Geological Survey (NTGS) for the Peel Project from 2004 to 2007.

The Imperial Formation comprises predominantly clastic marine deposits, with up to several decametre thick shale and sandstone packages. Previous studies have divided the Imperial Formation into two parts: a lower sand-rich interval, and an upper shale-rich interval. The sand-rich interval was interpreted to represent a lower shoreface to basin-floor sedimentary succession with

westward dipping clinoforms, and a terrestrial sediment source to the east or northeast; and the shale-rich interval as slope to basin-floor sediments. The terrestrial deposits related to the Imperial Formation deposition are not preserved. In previous projects, the Imperial Formation was only studied in the Peel areas of the NWT.

The Energy Group of the NTGS conducted a one-week scoping study in 2019 to examine five Imperial Formation outcrops: Carcajou River South, Imperial River, Mountain River, Powell Creek, and Gayna Gorge. Carcajou River South, the southernmost outcrop, is in the Central Mackenzie Valley area of the NWT and has not been studied previously. Here, the Imperial Formation comprises intercalated shales and tabular and weakly channelized sandstones. Current and wave ripples, decorated with cm-scale bioturbation, are common and indicate oxygenated shallow marine environments. Carbonate-rich debrites and tempestites suggest the presence of a carbonate shelf or platform that periodically contributed sediment to the clastic depositional system. At Imperial River, the sand-rich middle member of the Imperial Formation comprises an upward shallowing succession, with turbidites common in the lower part of the outcrop. Upward there is an increasing prevalence of current, wave, and interference ripples, bioturbation, and hummocky cross-stratification. Terrestrial vascular plant detritus in the form of mm to dm size coaly fragments is common. This shallowing upward trend was also observed during previous studies, and was interpreted as the result of a prograding shelf and shifting sediment flux. At Powell Creek, tabular sandstones were previously interpreted as a deep-water turbidite fan. During the 2019 study, the sandy part of the outcrop was divided into two units similar to that observed at Imperial River and in contrast to previous studies, indicating that shallow-water environments stretched further westward than

previously recognized. At Mountain River and Gayna Gorge, the observed portions of the Imperial Formation comprise only deep-water turbidite facies.

The results of the 2019 field season combined with previously obtained permeability and porosity data of the sandstones in the Imperial Formation highlight the need to devise a multi-year research program to research the Imperial Formation as a potential hydrocarbon source and reservoir.

WOODLAND CARIBOU WINTER RANGE SELECTION IN THE CENTRAL MACKENZIE VALLEY, SAHTÚ

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Boreal woodland caribou are a culturally important and politically charged species across Canada. Despite strict legislated requirements and strong societal desire to protect caribou habitat, little detailed information is available in the Central Mackenzie Valley about local caribou distribution or habitat use patterns. This knowledge gap means that management efforts cannot target areas of high habitat quality or high caribou use, but instead must be applied more broadly to prevent new disturbance even in locations of low habitat quality, where caribou do not occur, or where caribou are unlikely to occur.

In winter 2012-2013 caribou cratering locations and moose and wolf use data were collected along a network of aerial survey

transects between the Mackenzie, Carcajou, and Little Bear Rivers and the Canol Trail to identify caribou winter range and determine the characteristics of winter range. Kernel density estimates were used to identify caribou winter range and moose distribution within the study area. Caribou winter range and moose use showed very little spatial overlap within the study area. Next, a zero-inflated negative binomial modelling framework was used to test a series of hypotheses based on predation risk, escape terrain, habitat disturbance (natural and anthropogenic), and land cover to explain winter range selection patterns at two spatial and two temporal scales. Spatial scales were based on the Oil and Gas Leasing Grid Sections and Units to understand caribou decision making at scales that are immediately related to scales at which oil and gas exploration and development decisions are made. Sections and units also generally equate to first (274 ha; orientation on a landscape) and third (20 ha; food searching) order habitat selection for caribou. Temporal scales were used to assess whether dramatic shifts in winter range locations or characteristics occur over a winter season. At the broad scale caribou selected for winter range away from areas of high moose use and away from burns, regardless of burn age. At the fine scale caribou selected for winter range with a high proportion of lichen landcover. No temporal variation in selection patterns were observed. Thus, caribou are selecting for winter range at two spatial scales, simultaneously. At a broad scale caribou are selecting for locations with less alternate prey use (i.e., the spatial separation hypothesis to minimize predation risk) and at the fine scale caribou are selecting for locations with more food. Finally, caribou habitat selection patterns were used to show how to predict habitat quality outside of the immediate study area in a spatially explicit way. The predictive mapping shows where high-quality habitats may occur elsewhere and how such information may be used to inform management decisions around

where and how industrial land uses occur more broadly within woodland caribou habitats in the Central Mackenzie Valley.

USING ALTERNATIVE DATA SOURCES TO INFILL AND ATTRIBUTE LINEAR FEATURE DATASETS IN THE NORTHWEST TERRITORIES

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An ongoing challenge across the Northwest Territories (NWT) and western Canada for land managers and research scientists is a lack of attribute information for seismic lines and other linear features. Often the locations of lines are known (either collected from maps, spatial data, or digitized from air or satellite imagery), but information about how and when those lines were cut are not. Without those attribute data it is impossible to link a current line recovery state to severity of disturbance during initial construction or time since construction. This in turn limits myriad subsequent actions like estimating animal response to lines with variable amounts of vegetation recovery or forecasting line recovery rates. Such limitations often translate to keeping lines “on the books” forever which is unlikely to be ecologically realistic, but perhaps required from the perspective of a precautionary conservation strategy.

In this talk non-traditional sources of data were used to improve and attribute spatial datasets of known linear features in three different study sites across the NWT. Companies that license seismic data often

collect and catalogue various existing data and associated exploration program information into data libraries to market those data to interested parties. Also, all seismic exploration programs conducted in the NWT are reported on to a governing agency (historically to the National Energy Board; currently to the NWT Land and Water Board system) with a Geophysical Report explaining a variety of program information. These data streams were used to attribute line features in the official GNWT footprint dataset by assigning seismic line construction method, season, year, and width, updating converted seismic lines to new line type (e.g., pipeline, access, and road), and inferring whether a seismic line was reopened in a subsequent exploration program. Also missing lines and line segments were infilled using recent (2015 – 2018) satellite imagery. This work was done in the Checkpoint / Jean Marie River, Cameron Hills, and the Central Mackenzie Valley areas, selected because each were subject to different intensities of development pressure at different time periods. In all study areas, known lines were well represented in available datasets, but line attributes were not. For all study areas, attribute information was available for < 10% of lines in the official GNWT footprint dataset; using these methods the full suite of attributes was assigned to > 95% of all lines. In the Cameron Hills, where development activity transitioned from exploration to production, transition from seismic lines to other line types was also captured for 17% of lines.

EKATI LONG LAKE CONTAINMENT FACILITY (LLCF) RECLAMATION RESEARCH

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The Ekati Diamond Mine is a surface and underground diamond mine operated by Dominion Diamond Mines. It is located near Lac de Gras within the Northwest Territories, Canada approximately 300 km north of Yellowknife and roughly 200 km south of the Arctic Circle. The Long Lake Containment Facility (LLCF) is the primary containment area for processed kimberlite (PK) storage after the extraction of diamonds from kimberlite ore. The facility has been in operation since 1998 and is the main repository of PK from open pit and underground mines at the Ekati Mine. The overall reclamation goal for the LLCF is the design and construction of a long-term cover that will physically stabilize the PK, with a landscape that will be safe for human and wildlife use. The proposed final closure design for the LLCF includes the following components:

- Combination of vegetation and rock cover system to physically stabilize the PK. Vegetation is planned to be the main stabilization component of the PK. Rock placement is intended to promote a localized environment for vegetation growth and provide larger-scale wind and water erosion protection.

- Water drainage channels to convey surface water flow through the containment cells and into settling ponds.

Since 2012, reclamation research has been ongoing at Cell B of the LLCF with the overall intent of addressing uncertainties with the proposed final LLCF cover design. Separate reclamation research programs focused on addressing the uncertainties of vegetation growth in PK are being carried out under this project.

Dominion's short-term research goal has been to establish and evaluate the vegetation growth directly within PK. Main components of the LLCF reclamation research includes evaluation of soil amendments, rock/vegetation combinations, annual crop cover, plant species trials, mine-generated organic matter application, seed collection/distribution, and natural vegetation colonization.

The LLCF reclamation research aims to establish a best practice that could be adapted by other mining operations looking to reclaim PK containment sites. Annual vegetation monitoring and continued program expansion aid in reaching that goal. Recent program undertakings have included:

- Surface water management research through trial channel construction and further bio-engineering of existing channels
- Mycorrhizae inoculation to improve soil microbial communities
- Implementation of rough and loose mounding as an erosion control measure

- Evaluation of the feasibility of using organic matter generated from the Ekati composter facility
- Harvesting of halophytic seed and live plant specimens from saline environments near Kugluktuk, Nunavut for planting in Cell B
- Utilization of reclamation equipment for earthworks

The LLCF reclamation research has been a vessel for developing methods of utilizing PK as an effective growth medium. High sodium concentrations and low organic matter content present challenges, but also provide opportunities for innovative research to improve environmental conditions and lead to a final closure design. Dominion has included Traditional Knowledge, other scientific knowledge, as well as regulatory and community input as a key component of LLCF reclamation research planning and final cover design.

PRECIOUS METALS-RICH VMS MINERALIZATION AT NELSON LAKE, NWT

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The Archean Yellowknife Greenstone Belt is known for its shear zone-hosted gold deposits, dominated by the Giant Yellowknife Mine (pp 8.1 m oz. Au), Con Mine (pp 6.1 m oz. Au) and the high-grade vein deposit Discovery Mine (pp. 1 m oz. Au). The greenstone belt extends from beneath the waters of Great Slave Lake

northwards to beyond the Discovery Mine for over 100 km. Minor volcanic, quartzite and banded iron formation of the Central Slave Cover Group are overlain by mafic-dominated tholeiitic volcanic rocks of the Kam Group. These in turn are overlain by calc-alkaline intermediate and felsic volcanic rocks of the Banting Group which near the top are interbedded and overlain by turbiditic sediments of the Burwash Group. A number of distinct syn and post-depositional intrusions form dykes, sills and plutons within the greenstone belt. The Nelson Lake precious metal-rich VMS deposit was discovered within the Kam Group by following up a property-wide biogeochemical survey conducted in 2018. Initial grab samples up to 2.30 gpt Au, 360 gpt Ag, 3.83% Pb, and 1.94% Zn was followed up by a VTEM Plus ® airborne survey where seven isolated anomalies were prioritized. Recent trenching on the 5656 anomaly has exposed 0.4 to 2.1 m wide sulphide zones dominated by tetrahedrite, pyrrhotite, sphalerite, galena, arsenopyrite, and galena.

GETTING AGREEMENTS RIGHT – KEY FACTORS AFFECTING IMPLEMENTATION SUCCESS

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Since the days of the Whitehorse Mining Initiative in 1994, the mining industry in Canada has increasingly focused on improving its relationship with Indigenous communities. While there is always room for improvement, today the mining industry is recognized as one of the few industries creating meaningful

economic opportunities for Indigenous peoples and communities. Agreements, commonly known as Impact Benefit Agreements or IBAs, are currently the primary tool used by communities and companies to identify and realize these opportunities.

Despite their importance, existing research has primarily focused on the content of agreements and negotiation approaches there is less information on what successful implementation of an agreement looks like, and the key factors that influence implementation success. Drawing on relevant literature and interviews with stakeholders and rightsholders, Stratos has been identifying these factors. This presentation will summarize preliminary findings from this research, including a life-cycle framework that identifies implementation success factors in four stages: pre-negotiation, negotiation, implementation, and monitoring as well as factors that cut across all stages.

DIAMOND POLICY FRAMEWORK

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Established in 1999, the Diamond Policy Framework (DPF) was designed to facilitate the development of a diamond manufacturing industry in the Northwest Territories (NWT). In addition, agreements with NWT diamond producers were established which required them to offer 10 percent of their production, by value, to Approved NWT Diamond Manufacturers (ANDM) for manufacturing in the NWT.

The NWT is the most expensive jurisdiction in which to operate a manufacturing facility and despite some early success, the policy was not successful in creating an operating environment for the secondary industry to flourish.

In 2018, ITI commissioned a review of the DPF that sought recommendations on how to make this industry more attractive to investors. The report contained a detailed review of the global diamond market. It also presented a series of cost per carat analyses of NWT production costs versus costs in other diamond manufacturing regions.

Policy recommendations included adopting an export provision for NWT rough diamonds (and making that export volume contingent on their investment in the NWT), permitting the development of a facility for high-skill planning and lasering services, and generally ensuring that the policy supported the acceptance of innovative business plans.

In 2018, The Department of Industry, Tourism and Investment (ITI) amended the DPF. Accordingly, a new approach to the utilization of rough diamonds was developed to realize maximum economic benefits for the NWT and its residents.

The amended DPF now has provisions that allow an ANDM to export a portion of their allocation based on their business proposal and an ANDM is no longer required to complete the entire manufacturing process in the NWT.

To be eligible to export rough diamonds, ANDM applicants must provide a comprehensive business plan that outlines investment details. Business plans are reviewed and scored based on a comprehensive matrix that determines the export volume.

THE CANADIAN MINERALS AND METALS PLAN

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The Canadian Minerals and Metals Plan (the Plan) was launched on March 3, 2019. The Plan aims to solidify Canada's position as a global mining leader, and to lay the foundation for lasting success at home and abroad. It focuses on six Strategic Directions: Economic Development and Competitiveness; Advancing the Participation of Indigenous Peoples; the Environment; Science, Technology and Innovation; Communities; and Global Leadership.

The Plan was informed by direction from Canada's Mines Ministers, input from engagement sessions held in almost every province and territory, research and analysis prepared by government subject matter experts and external consultants, and over 25 independent reports.

Through the Canadian Minerals and Metals Plan Secretariat, housed in Natural Resources Canada, the federal government is continuing to collaborate with the provinces and territories to develop draft actions to operationalize the Plan. At the July 2019 Energy and Mines Ministers' Conference, Mines Ministers advanced the discussion of six pan-Canadian actions under the Plan. These will be included in the first of a series of Action Plans set for release in 2020.

The Action Plan will consider areas where industry, government, partners and stakeholders can focus their efforts to boost

competitiveness, position Canada to take advantage of opportunities, and translate our leadership into benefits for Canadians.

Through the Action Plan, industry can continue to demonstrate leadership, including by collaborating to help solve the big, common innovation challenges that they identify.

The federal government will leverage the Plan to support jobs and development across regions, to advance reconciliation with Indigenous Peoples, to capitalize on Canada's reputation in a clean economy, and to support sustainable natural resource development.

Subsequent Action Plans will keep this initiative evergreen, respond to new challenges, and capitalize on longer-term opportunities in the industry. The Mining Sector Performance Report will be used to evaluate the progress of the Canadian Minerals and Metals Plan.

DECADAL-SCALE FOREST FIRE EFFECTS INTENSIFY RECENT THAW-DRIVEN MASS- WASTING IN THE CENTRAL MACKENZIE MOUNTAIN FOOTHILLS, NWT

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Hillslope thermokarst mass-wasting encapsulates climate-driven geomorphic processes in glaciated terrains that have the potential to rapidly mobilize large amounts of thawed material into surrounding aquatic ecosystems. We identify over 400 recent thermokarst mass-wasting features, including retrogressive thaw slumps, active layer detachments, and deeper-seated translational landslides within the upper Keele and Redstone River watersheds (~ 4000 km²) in the central Mackenzie Mountain foothills, NWT, Canada. This area represents the southernmost concentration of widespread thaw slump related permafrost mass-wasting in northwestern Canada. The surficial geology consists largely of morainal material up to 20 m thick in plateaued areas, with lacustrine, alluvial, and colluvial sediments typically

accommodating lower river valleys. Several thaw slumps that were visited display headwalls consisting of diamicts from the late Wisconsinan Laurentide Ice Sheet and include metre-scale ice lenses at their bases. Investigation of satellite imagery (1993-present) shows most of these features have initiated and rapidly expanded in the last 10-15 years. Increases in disturbance size and growth rate are consistent with regional increases in air and ground temperatures and summer precipitation during this time span. The largest retrogressive thaw slump documented initiated post-2005 and can be termed a 'mega-slump', with a headwall height of over 25 m and total disturbance area of ~ 25 ha. Patterns of accelerated mass-wasting are well-constrained by the extents of forest fire activity from the mid to late 1990s. The close association between historic fire and permafrost mass-wasting suggests a legacy influence of thermal disturbance from forest fires as a primary preconditioning mechanism for the initiation of these permafrost mass-wasting features. Additionally, the acceleration of such disturbances is also associated with the translocation of large volumes of thawed sediment into underlying river valleys, exceeding river transport capacity and creating distinct valley-fill deposits. Using ground-truthed satellite and unmanned aerial vehicle (UAV) mapping, in conjunction with novel lab-based permafrost characterization, we aim to provide a basis for evaluating climate-driven trajectories of comparable terrains throughout northern Canada.

Abstracts - Poster Presentations

Presenting author denoted by *

INTEGRATION OF SCIENCE INTO LAND AND RESOURCE DECISION-MAKING: A CASE STUDY OF REGIONAL LAND USE PLANNING

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In the Northwest Territories (NWT), regional land use plans are the primary land management tools that guide decisions on what land use activities are permitted or prohibited and under what conditions. It is imperative that relevant and current scientific information is integrated into this multi-party decision-making process. There is a plethora of scientific information that is relevant to regional land use planning, including environmental, social, cultural, and economic research. The integration of science into land use planning decision-making is challenging given the regional scale of land use planning in the NWT and a lack of synthesized information and decision support products. This poster outlines three projects that the Government of the Northwest Territories, Department of Lands, is leading to support the integration of scientific information into land use planning decision-making in the NWT. The first is the results of an inventory and mapping project of

peer-reviewed research to inform pre-planning work in the southeast NWT. The second is an ongoing project to produce community change detection maps within flood risk areas. And the third is a new project to investigate ways of integrating climate change into regional land use plans, including a preliminary jurisdictional review.

VOLCANIC, SEDIMENTARY, AND DEFORMATION HISTORY OF WINTER LAKE GREENSTONE BELT, SLAVE CRATON, NORTHWEST TERRITORIES: PRELIMINARY RESULTS FROM THE 2019 FIELD SEASON

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The Archean Winter Lake greenstone belt (WGB) in the Slave craton, Northwest Territories, has been relatively underexplored compared to other supracrustal belts in the Slave craton, but shows potential for base-metal

mineralization. It is situated ~250 km northeast of Yellowknife and consists of lower greenschist to upper amphibolite grade mafic to felsic volcanic rocks and sedimentary rocks that are surrounded by ca. 3.3 to 2.9 Ga granitoids of the Central Slave Basement Complex (CSBC).

The overall objective of this study is to increase our understanding of the origin and geodynamic evolution of the WGB and to evaluate its economic potential. The project aims to increase knowledge of the tectonic setting of volcanic and sedimentary rocks of the WGB and their relationships to the CSBC granitoids. In 2019, as part of a larger Northwest Territories Geological Survey mapping initiative, three weeks were spent bedrock mapping near Newbigging Lake and one week near Big Bear Lake (at 1:5,000 and 1:10,000 scales, respectively). At these locations, detailed mapping (1:2,000) of the mafic volcanic sequence was also completed to generate a lithostratigraphy for the southern WGB. This program enabled us to evaluate the nature of contacts, previously interpreted as unconformities, between the CSBC, the ca. 2734-2924 Ma Central Slave Cover Group (CSCG) volcanic and sedimentary rocks, and post-volcanic sedimentary and granitoid rocks. Mapping near Big Bear Lake also allowed the examination of a previously mapped ~ 1.3-1.7 km wide rhyolite interpreted to be part of the ca. 3.3 Ga Newbigging Formation. Based on field observations, the formation does not include a rhyolite *sensu stricto* but rather a succession of weathered mafic to intermediate volcanic and intrusive rocks. This field season, the first of three, also led to the discovery of several semi-massive to massive sulfide showings within the mafic volcanic sequence, and the identification of sulfides (interpreted as

remobilised) and multiple younging indicators within the younger conglomerate unit that are necessary for our lithostratigraphy study.

Future geochronological analysis of U-Pb detrital zircon ages and Sm-Nd isotope geochemistry of the polymictic metaconglomerates and the CSCG quartzite will enable us to determine their sources and age. Together with absolute timing of thermotectonic events, an Archean oceanic and continental crust geodynamic evolution model will be produced. The variability of crustal contamination determined through trace element and Sm-Nd isotope geochemistry of the mafic volcanic sequence will be investigated to understand their genesis and associated tectonic settings. A petrogenetic study of the mafic volcanic sequence that hosts the sulfide mineralization combined with detailed mapping of volcanic and sedimentary lithofacies will define facies distribution and the volcanic and sedimentary architecture across the WGB. It will also determine depositional environment for the volcanogenic massive sulfide (VMS) -type mineralization, present a new criterion for VMS deposit exploration for this specific belt, create the basis of a WGB VMS genetic model, and aid in our understanding of VMS formation in the Slave craton.

STRUCTURAL EVOLUTION OF THE WESTERN MARGIN OF THE SOUTH RAE CRATON, NORTHWEST TERRITORIES: PRELIMINARY RESULTS

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The Nonacho Lake area of the South Rae craton, Northwest Territories, consists of ca. 1.91-1.82 Ga conglomerate, sandstone and mudstone of the Nonacho Group unconformably overlying Archean to Paleoproterozoic granitic and gneissic basement rocks. The Nonacho Group is interpreted as a mostly fluvial sequence deposited in a sinistral strike-slip basin.

There is a substantial metamorphic break between the 2.05-1.92 Ga greenschist-facies metamorphism in the Porter domain 45 km east of Nonacho Lake and the 2.08-1.95 granulite-facies metamorphism in the southwestern Taltson Magmatic Zone west of Nonacho Lake. This metamorphic discontinuity suggests the presence of a significant structure between the Taltson basement complex (Tbc) and the Porter domain. Moreover, the ca. 2.4 Ga (Hbl) and 2.3 Ga (Bt) ⁴⁰Ar/³⁹Ar cooling ages recorded in the Porter domain contrast with the younger (ca. 1.85 Ga) cooling ages recorded in the Tbc, and necessitate the presence of a major structure

that accommodated the ca. 1.85 Ga exhumation of the 2.08-1.95 Ga high-grade metamorphic rocks of the Tbc.

The goal of this project is to investigate the deformation history of the western flank of the South Rae craton, in the Nonacho Lake area, by constraining the geometry, kinematics and timing of major domain-bounding structures, documenting the exhumation history of the crustal blocks, and examining potential temporal and spatial links between these major structures and structures that host polymetallic (Cu-Au-Ag) and U+/-REE mineralization. Detailed mapping during the 2019 field season involved ground truthing of structures delineated from aeromagnetic data. This revealed three major SW-striking ductile shear zones, informally termed the Udder Island shear zone, Magrum Lake shear zone, and Gray Lake shear zone. Located along the western flank of the Nonacho group, the Udder Island shear zone is 1-2 km wide with a strike length of at least 70 km and likely extends as far as the Athabasca basin in Saskatchewan. The shear strain is most notable within siltstone of the Chief Nataway formation and some basement units. The zone dips steeply to the NW and displays a strong sub-horizontal stretching lineation and ubiquitous sinistral shear sense indicators. The 2-3 km wide Magrum Lake shear zone bounds the eastern margin of the Nonacho Group and has been traced for at least 30 km. Sandstone and basement units have a steeply NW-dipping shear fabric and stretching lineations plunging shallowly to the SSW, that indicate oblique normal and sinistral movement. The Gray Lake shear zone consists of K-feldspar porphyritic granite and tonalite-amphibolite gneiss with a steeply NW-dipping shear fabric, and appears to separate the higher-grade Archean rocks of the Porter domain from the lower-grade rocks to the west.

Future work will include: 1) $^{40}\text{Ar}/^{39}\text{Ar}$ thermochronology to constrain timing of basement uplifts and delineate crustal-scale boundaries; 2) U-Pb geochronology of syn-to-post tectonic granitic dykes to constrain timing of deformation and shear zone development.

TRACE ELEMENT PARTITIONING BETWEEN APATITE AND KIMBERLITE MELTS: IMPLICATIONS TO CRYSTALLIZATION CONDITIONS OF KIMBERLITE MAGMA

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Kimberlites are the deepest mantle magmas to reach the surface of the Earth and the hosts of the major primary diamond deposits. The enigmatic nature of kimberlites owing to poorly constrained triggers of kimberlite magmatism, melt composition, and crystallization conditions, are mostly limited by unknown content and composition of volatiles. The content and ratio of H_2O and CO_2 are important parameters of magma emplacement. They are essential for the mantle melting and rapid ascent of kimberlites. Volatiles also greatly affect diamond preservation in kimberlites during the ascent to the surface. Apatite has been used as an indicator of volatiles in different

magmatic systems. Partitioning of trace elements between apatite and a melt is also sensitive to the carbonate component in the melt. This makes apatite potentially very useful indicator of evolution of melt composition and fluid during kimberlite ascent and emplacement. However, trace element partition coefficients between apatite and melts have been determined for compositions much more SiO_2 -rich than kimberlites, whereas coefficients in carbonate melts show large discrepancies. This study presents experimentally determined trace element partition coefficients (D) between apatite and synthetic analogues of kimberlite (SiO_2 content ranging from 11 to 23 wt%) and carbonatite melts (SiO_2 content <1 wt% and 4.5 wt%). The experiments were conducted in piston-cylinder apparatus at 1150°, 1250°, 1350°, at 1 and 2 GPa, and at oxygen fugacity - 3.97, 0.27, 4.83 log units relative to fayalite-magnetite-quartz (FMQ) buffer. We demonstrate the increase of DREE for Rare Earth Elements (REE) with increase in SiO_2 of the melt and the effect of apatite composition (natural Durango apatite vs. synthetic apatite) on D and substitution mechanism. We found no effect of temperature, pressure, water content, and oxygen fugacity on D in these low SiO_2 melts. This allows us to use trace element content of natural apatite to examine the composition of kimberlite magma. We apply the results to apatite from two kimberlite classes: Class 1 composite kimberlite pipe from Orapa cluster (Botswana) with hypabyssal coherent and volcanoclastic kimberlite facies and Class 3 kimberlite pipes from Ekati Mine (Northwest Territories, Canada) filled with effusive coherent kimberlites in Leslie pipe and both volcanoclastic and coherent kimberlites in Boa pipe, and discuss how changes in SiO_2 content of kimberlite melt affect apatite saturation. We further apply our experimentally determined DREE to model the composition of evolved kimberlite melt using published bulk rock and apatite compositions in kimberlites.

FOCUSED FLUID FLOW ON NORTHWEST-ORIENTED FAULTS, BANKS AND VICTORIA ISLANDS, NORTHWEST TERRITORIES

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Banks Island, Northwest Territories is in the southwest Arctic Islands, bordering the Arctic Ocean about 250 km northeast of Tuktoyaktuk. Banks Island is underlain by: i) Neoproterozoic Shaler Supergroup; and ii) sediments of the lower Paleozoic Franklinian Basin. Compressional folding of these rocks occurred sometime between deposition of the youngest Paleozoic sediments (Upper Devonian) and the age of sediments above the Lower Jurassic angular unconformity. Rocks that overlie deformed Devonian strata are: iii) Jurassic-Cretaceous strata deposited in the Banks Graben; and iv) Cenozoic strata that blanket much of the island.

Interpretation of the complex structural history was carried out through a combination of field studies, seismic mapping and low temperature thermochronology. Numerous faults at several orientations and of multiple generations crosscut Mesozoic and Cenozoic strata. Most faults within the Banks Graben have a dominantly normal sense of motion, and most are parallel to the NE-SW trend of the Banks Graben. Local indications of strike-slip movement are present at the eastern margin of the Banks Graben where Cenozoic strata are folded. Regional extension during opening of the Arctic Ocean likely drove growth and movement of these faults.

A series of NW-SE trending faults are present on the southeast side of the Banks Graben and extend onto northwestern Victoria Island. These NW-SE oriented faults are at a high angle to the dominant extensional trend related to the opening of the Arctic Ocean. They show normal sense of movement and are mapped on the surface, imaged on seismic and on gravity data. One of these faults is well exposed at Nelson Head on southern Banks Island. A detrital apatite fission track sample from the Shaler Supergroup at this location contains three age populations with pooled ages of ca. 385 Ma, 205 Ma, 85 Ma. Thermal history modelling indicates two thermal events, one in the Paleozoic (400-300 Ma) followed by cooling from Carboniferous to Early Cretaceous, and a thermal event in the Cretaceous between 130 Ma and 80 Ma with models indicating cooling occurring subsequent to 80 Ma. This is in agreement with a seismic imagery in Amundsen Gulf that shows that these NW-SE faults were active in Late Cretaceous time because the Kanguk Formation thickens across these faults. The faults were active into the Cenozoic as demonstrated by faulting offsets in Eureka Sound Formation at Nelson Head.

The NW-SE trending faults appear to be associated with hydrothermal dolomite in the Kusrhaak D-16 hydrocarbon exploration well, where Devonian Blue Fiord Formation carbonates contain dolostone breccias, vertical stylolites, dissolution features, saddle dolomite, quartz, and late-stage bitumen. Till sampling by the GSC on NW Victoria Island in the 1980s identified one zinc anomaly. This anomaly overlies a NW-SE trending fault. The NW-SE faults appear to have focussed hydrothermal fluids either in Late Cretaceous time, or at some as-yet unresolved time of motion in the late Paleozoic or early Mesozoic.

THE EFFECT OF POST DEPOSITIONAL MELTWATER PROCESSES ON KIMBERLITE INDICATOR MINERAL CONCENTRATIONS IN GLACIAL SEDIMENTS

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In the glaciated terrain of the Northwest Territories, successful diamond exploration projects depend on the implementation of drift prospecting. Drift prospecting combines surficial sediment sampling with an understanding of glacial sediment transport history so that geochemical anomalies can be properly interpreted. However, deglacial meltwater processes that may rework, erode, transport, and deposit previously emplaced till are commonly overlooked or misidentified in sample collection and data interpretation. Exactly how deglacial meltwater processes affect the concentration of kimberlite indicator minerals in glacial sediments is poorly understood. The aim of this study is to determine if syn- and post-depositional meltwater processes affect kimberlite indicator mineral concentrations and distributions.

The study area is approximately 225 km², located in the Winter Lake area, in the southern Slave region. This area was chosen

for its multiple subglacial meltwater corridors with numerous meltwater related landforms adjacent to relatively unmodified till. It is a prospective area for kimberlites based on the kimberlite indicator minerals identified during previous till sampling programs.

The project incorporates terrain mapping, fieldwork and geochemical analysis. Progress so far includes a desktop study using existing air photos and surficial maps of the region and fieldwork. Stereo image visualization and mapping software (Summit Evolution™) combined with digital air photos of the area were utilized to complete a preliminary 1:10 000 scale digital terrain map. Fieldwork was completed in the summer of 2019: the nature and distribution of surficial materials were described, ice flow indicators identified and recorded, and surficial material samples collected. Sampling targeted sediments that experienced varying degrees of meltwater modification; materials collected cover the spectrum from unmodified till to washed till to sorted glaciofluvial sand and gravel.

Analysis and interpretation are ongoing. Clast shape and lithology analysis has been completed. Grain size analysis will be completed for the presentation. Samples have been sent to commercial labs for geochemical analysis of the silt and clay fraction as well as heavy mineral separation followed by picking of kimberlite, base metal and gold indicator minerals. Potential kimberlite indicator minerals will be analyzed by electron microprobe to verify the mineralogy; their chemistry will be related to diamond potential. The results of these analysis will not be available in time for the presentation. Field descriptions and photogrammetry indicate that many meltwater corridors contain hummocks and elongate ridges composed of diamicton that is sandier and contains less silt

than an unmodified till. The morphology and directionality of these identified landforms suggest they are not esker segments. Comparison of grain size, clast shape and lithology data between till and modified sediments will be related to landform genesis.

The observations of surficial materials, landforms and ice flow indicators are being used to update the preliminary 1:10 000 scale terrain map of the area, as well as to interpret the local glacial history of the study area. The results of this project will have significant implications in the planning and execution of diamond exploration programs in the Northwest Territories as well as in effectively interpreting the results of drift prospecting campaigns.

MELT AND FLUID INCLUSION SYSTEMATICS OF THE CANTUNG W (CU, AU) SKARN DEPOSIT, NWT, CANADA: MODELING W ENRICHMENT AND FLUID COMPOSITION IN THE ADJACENT MINE STOCK INTRUSION

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The Cantung W (Cu, Au) skarn deposit, Northwest Territories, Canada is a world-class calc-cilicate skarn deposit hosted by the Cambrian Sekwi Formation limestone, near its contact with the Cretaceous Mine Stock monzogranite. The limestone was affected by the Mine Stock in three ways, i) contact metamorphism during initial emplacement and cooling of the intrusion, ii) magmatic fluids associated directly from the intrusion and iii) fluids that used the same pathways as the magma that formed aplitic dykes. Skarn mineralization (scheelite) occurred from magmatic fluids derived either from the proximal intrusion or by late-stage aplitic dykes. Previous work on the Mine Stock monzogranite, immediately below the E-zone orebody, identified coeval silicate melt and fluid inclusions, and zircon inclusions, in apatite. All which provide a unique opportunity to understand the enrichment in, and transfer of, metals between fractionated granitic melts and immiscible aqueous fluids responsible for the formation of the high-grade W-skarn deposits.

Preliminary fluid inclusion petrography indicate very small (~5 µm wide) liquid-rich fluid inclusions with a minor vapour bubble. This study will investigate the melt and fluid inclusion systematics of the apatite from the Mine Stock. A multi-microanalytical approach will be undertaken to determine the i) minimum entrapment temperatures, fluid composition and salinity using microthermometric analysis of the fluid inclusions, ii) major element composition including halogens of quenched melt inclusions to classify the melts, iii) temperature of apatite crystallization (i.e., inclusion entrapment) using electron probe microanalysis of biotite/apatite pairs for F/Cl thermometry, and iv) temperatures of zircon crystallization via LA-ICP-MS using Ti-in-zircon thermometry. Results

will be used to model P-T-X conditions during inclusion entrapment. Fluid inclusion data will be compared to the already established fluid inclusions systematics of the ore zone in order to constrain mineralizing fluid compositions and model processes of W enrichment in the granitic intrusions.

TOWARD A NEW GLACIAL GEOLOGY FRAMEWORK SUPPORTING GEOSCIENCE APPLICATIONS IN THE SOUTHWESTERN GREAT SLAVE LAKE AREA

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A better understanding of the Northwest Territories surficial geology is important for addressing topics such as natural resource extraction, permafrost change, infrastructure development, and land use management. The area surrounding southwestern Great Slave Lake (NTS 85C/85F) is one such region requiring greater surficial geological

understanding. This region includes several towns and communities, important infrastructure (highways, railroads), is within the discontinuous permafrost zone, and is considered to host a significant mineral resource potential. Our research aims to improve understanding of Laurentide Ice Sheet (LIS) dynamics and evolution of glacial Lake McConnell, as well as the nature and distribution of surficial sediments, regional stratigraphy, and permafrost landforms.

Previous interpretations of ice-flow in the area indicated a generalized westward trajectory. New ice-flow erosional indicators (n=66) provide evidence for an oldest southwest flow (230°), followed by an intermediate westward flow (280°), and a later northwestward flow (305°). Stratigraphic observations and sediment properties (n=160) indicate three distinct till units. The lowest (oldest) till observed is a grey diamicton sourced mainly from local Paleozoic sedimentary rocks. A southwestward ice flow direction is interpreted for this unit based on clast fabrics and is consistent with the oldest erosional ice-flow indicators. The lower till is overlain by a brown diamicton containing a higher proportion of far-travelled Canadian Shield clasts. This brown till contains lodged, elongate boulders with parallel striations on their upper surface and clast fabrics indicating a west to northwestward ice-flow direction, broadly consistent with the interpreted intermediate ice-flow phase. The third till, with a dominant local bedrock provenance, forms a discontinuous unit at surface across the study area. Although no clear stratigraphic constraints were found, the third till appears to be related to the final ice-flow phase. Streamlined landforms, moraines, and other sediment-landform assemblages previously understudied in the region have now been mapped and analyzed in greater detail and further

supporting LIS dynamics interpretations and deglacial history.

Minimum deglacial age estimates are better constrained through optical dating of medium-sand deposits in a well-developed raised beach (n=2) and relict aeolian dunes (n=7). Optical dating results indicate distinct shoreline development associated with the retreat of glacial Lake McConnell, and phases of dune development following lake drainage. Interpretation of local LIS dynamics and ice-margin retreat enhances our understanding of the western LIS and will inform practical applications of surficial geology in the southwestern Great Slave Lake area.

COMMUNITY SURFICIAL GEOLOGY AND GEOHAZARDS MAP SERIES, FORT MCPHERSON, NORTHWEST TERRITORIES, CANADA

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In many northern Canadian communities, buildings are supported in or on permafrost. Permafrost degradation due to climate warming can impact these building foundations, as well as nearby slopes whose stability often depends on remaining frozen. Community mapping can therefore be a useful strategy in land-use planning.

Two series of maps, describing community surficial geology and geohazards, including permafrost-related geohazards, were compiled with the assistance and support of Ecology North, the Hamlet of Fort McPherson, and the Rat River Development Corporation Ltd., as one of several proposed adaptations to climate change in Fort McPherson that required geotechnical engineering and permafrost expertise. Additional maps were developed to demonstrate changes in slope vegetation (trees and shrubs) over several decades to correlate with areas of slope movements and development. Another map presented a visual slope retrogression analysis and recommended setbacks. The map series were intended to be desktop-level maps that would accomplish the following tasks:

1. Help the community better understand the soils, rock and permafrost conditions around them, including geohazards related to those conditions;
2. Provide a tool to assist land managers with land use and development: to determine the preferred areas for building and avoid areas unsuitable for the future development; and
3. Provide a baseline reference for monitoring potential permafrost degradation or large-scale changes in the permafrost conditions and/or slope stability, resulting from climate change and/or human-induced impact.

PRELIMINARY BENEFICIATION STUDIES OF MACTUNG PHOSPHATE

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A preliminary beneficiation study of the unskarned and skarned phosphate rocks associated with the Mactung tungsten deposit, located in southwestern Yukon, along the border with the Northwest Territories (NWT), was carried out at the University of Alberta. The phosphate mineralization extends regionally, beyond the tungsten deposit and over 50 Mt of unclassified global phosphate resources grading about 10% P₂O₅ have been estimated within a 4 km² area around the site. The current Mactung mine plan has focused on the large tungsten deposit and has not considered the potential for simultaneous extraction of the phosphate.

The objective of the study was to evaluate the feasibility of beneficiating the phosphate to a saleable byproduct such as a concentrate meeting fertilizer feedstock requirements. Such a byproduct might not only be an economic “sweetener” to the tungsten mining, it could also partly satisfy Canada’s large phosphate market, which is currently wholly imported. The current sources are from other jurisdictions including some with significant geopolitical and socio-economic risks such as Western Sahara. Retaining the phosphate in the mine tailings may also have costs which include preventing potential environmental liabilities from any leakage into a drainage system.

Parameters tested in the study include the grindability of the ores and the separation of the phosphate mineral from the associated gangue phases. Both the unskarned and skarned ores were hard, with Bond Work Indices of 16.19 and 19.04 kWh/t, respectively.

Processing of low-grade sedimentary phosphate rock containing abundant carbonate gangue phases is generally challenging because of the similar metallurgical characteristics of apatite and carbonate minerals. Comminuted ores were subjected to direct and reverse batch flotations, which are the industry standard methods for processing phosphate ores. The flotation tests were conducted using varied dosages of flotation reagents commonly used in industrial operations to beneficiate phosphate ores. A combination of both direct and reverse flotation of the unskarned ore at a grind size of 83% passing 106 µm produced a phosphate concentrate with 25.86% P₂O₅, 14.88% SiO₂, 0.57% MgO, and 44.64% CaO, at a P₂O₅ recovery of 56%. A better concentrate with a higher P₂O₅ grade (28.68%) and recovery (70.9%), 46.98% CaO, and 0.72% MgO was obtained from the skarned ore at a grind size of 86% passing 53 µm. Reverse flotation of both ores using Armeen 18D as a collector for quartz and silicate gangue phases and corn starch to depress phosphate produced dismal results due to higher losses of phosphate into the froth.

Although none of the concentrates met the phosphate fertilizer feedstock requirements of >30% P₂O₅ and CaO/P₂O₅ < 1.6, and MgO < 1%, the concentrate from the skarned ore is very close. With further optimization of reagent dosages in a flowsheet involving both direct and reverse flotations, it is likely possible to produce a satisfactory concentrate that can be used to produce phosphate fertilizer.

Further research should be focused on optimizing reagent dosages, reducing reagents consumption, and using new collectors and depressants.

CHARACTERIZATION OF URANIUM MINERALIZATION IN THE NONACHO BASIN, NORTHWEST TERRITORIES

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The siliciclastic Paleoproterozoic Nonacho Basin, deposited on the western margin of the Rae craton, contains numerous uranium occurrences near its unconformable contact with crystalline basement rocks. Many of the uranium occurrences occur around MacInnis Lake, in the southwestern portion of the basin. In spite of being the subject of mineral exploration since the 1950s, there are no recent comprehensive studies on the occurrences aimed at understanding their formation (e.g., timing, physicochemical conditions, fluid and metal sources). Similarities in some geological features suggest that the Nonacho occurrences may be analogues of the world-class unconformity-type uranium deposits (UTUDs) in the Athabasca Basin, Saskatchewan. Although the available drill results from Nonacho occurrences do not suggest significant grade or tonnage, they are relevant in providing a comparative example to better understand the

conditions that yield fertile intracratonic basins that can host UTUDs. Additionally, they provide insights into the metallogeny of the basin.

Field work in August 2019 examined fifteen occurrences to document mineralization, alteration styles, and host lithology, while collecting representative samples for further study. Mineralization is hosted within basement granitoid, gneiss, and gabbro, and overlying sedimentary rocks, including arkosic conglomerate and interbedded sandstone-mudstone, in fracture and high-strain zones. In many areas the host rock type is uncertain, as it appears that both the basement granitoid and overlying sedimentary package have undergone extensive alteration and weathering. Uranium mineralization occurs predominately as veinlets (~2 mm thick) in a variety of host rocks, and (at one showing) it is associated with heavy mineral layers within arkosic conglomerate. Secondary uranium mineralization, characterized by yellow staining, is prominent around primary mineralization due to remobilization of uranium during surficial weathering. Early buff yellow clay alteration pervasively replaces basement rocks proximal to the unconformity near site of mineralization. The clay may be related to low temperature paleoweathering processes. Uranium mineralization appears coeval with coarse-grained, lath-like black chlorite alteration that occurs in veinlets and stringers and crosscuts clay alteration. Chlorite veins often contain copper sulphides (e.g. chalcopyrite, bornite). Quartz-feldspar±magnetite veins (cm-dm thick) are also present at sites of uranium mineralization in both the basement and the Nonacho sedimentary package. These quartz-feldspar veins are locally saussuritized, and cross-cut by black chlorite, suggesting they predate uranium mineralization but their genetic relationship is currently unclear.

By combining field data, petrographic observations, a range of complementary geochemical and microanalytical techniques (e.g., bulk-rock geochemistry, fluid inclusion petrography and microthermometry, laser ablation inductively-coupled plasma mass spectrometry and radiometric age dating), this project aims to: (i) characterize the styles of uranium mineralization, noting similarities and differences between their structure, mineralogy, mineral chemistry and paragenesis of mineralization and associated alteration; (ii) constrain the absolute age of mineralization, (iii) determine sources for metals and fluids, and (iv) classify the mineralization type (e.g., UTUDs). This information will add to the current understanding of the metallogeny, fluid history, and structural evolution of the Nonacho Basin. Additionally, it will provide constraints on the conditions required for fertile and infertile intracratonic basins with respect to UTUDs.

APPLICATIONS OF PORTABLE X-RAY FLUORESCENCE ANALYSIS TO EXPLORATION IN THE YELLOWKNIFE GOLD BELT

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The Yellowknife Greenstone belt is one of the major gold camps within Canada. Since its

discovery, gold has played a crucial role to the development of the city of Yellowknife and the economy of the Northwest Territories. Gold mineralization within the Yellowknife Greenstone Belt is not confined to one type of lithology or structure, but rather extends across multiple formations, with multiple generations of mineralizing fluids. The orogenic gold deposits of the Yellowknife Greenstone Belt commonly occur in shear zones where numerous structures have varying degrees of mineralization. Due to the low concentrations of gold required to make a mine, assaying is commonly required to evaluate the potential of an exploration target. However, drilling prospective structures and sending samples into an assaying lab takes a significant amount of time and resources. Standard assaying methods are expensive and often offer limitations due to the nugget effect inherent to gold mineralization and the destructive nature of wet chemical analyses.

In this study we aim to identify elements that can act as geochemical indicators with concentrations high enough to be detected by portable X-Ray Fluorescence (pXRF) and determine whether there is a relationship between these indicators and mineralized structures with high gold grades. The ability of pXRF to provide a fast and accurate assessment of compositions depends on particle sizes and chemical homogeneities within various lithologies. Therefore, we have further tested the precision and accuracy of pXRF with regards to heterogeneous whole rock samples from six drill cores from various locations across the Yellowknife Greenstone Belt. The precision and accuracy of the instrument has been tested through the study of sample duplicates and comparison of pXRF results with standard assay data and ICP data from TerraX Minerals. Portable X-Ray Fluorescence (pXRF) technology

offers a unique opportunity to assist companies in speeding up the preliminary assessment of potentially mineralized structures and perform such analyses in a non-destructive fashion.

PRELIMINARY BENEFICIATION STUDY OF SELWYN BASIN BARITE ORE

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A preliminary test beneficiation of the Selwyn Basin barite ore from the Northwest Territories was carried out in the Department of Chemical and Materials Engineering, University of Alberta. The test was carried out on a composite sample from the Anita and Wise showings. The feed grade was 28.67% Ba (corresponding to 48.7% barite) and 42.59% SiO₂, and the objective of the study was to produce a drilling fluid-grade barite concentrate with a specific gravity > 4.22. Both showings of barite are in the Canol Formation, a shale unit, with quartz and other silicates being the main gangue phases.

Mapping and historic intermittent exploration by government and private entities have documented the regional occurrence of barite mineralization throughout the Selwyn Basin. However, previous test processing by Baroid of Canada in the 1970s failed to produce a concentrate with satisfactory characteristics. In this study, we tested the susceptibility of the ore to grinding using the standard Bond Work Index as well as the ability to separate barite

from the associated gangue using gravity and batch flotation. According to our results, the Selwyn ore is medium to hard, with a Bond Work Index of 14.65 kWh/t. At a predetermined optimal grind size of 82% passing 106 µm, we were unable to produce a clean barite concentrate by gravity separation alone because of the preferential overgrinding of barite over gangue phases.

A satisfactory concentrate grading 54.39% Ba (equivalent to 92.5% barite and 4.27% g/cm³ density) at 81.4% barite recovery was produced at a grind size of 84% passing 53 µm, through direct flotation using sodium carbonate as pH modifier, sodium silicate as quartz/silicate depressant, and sodium oleate as barite collector. The successful flowsheet involves one rougher flotation stage and two cleaner stages in an open circuit. Closing the circuit by circulating the cleaner tailings and the scavenger concentrate is expected to further improve barite recovery.

PRELIMINARY RESULTS OF SCHEELITE COMPOSITION IN TUNGSTEN SKARN-TYPE AND REDUCED INTRUSION- RELATED GOLD DEPOSITS IN THE TUNGSTEN-TOMBSTONE BELT, CANADA

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Scheelite (CaWO_4) is a hydrothermal mineral that occurs in numerous deposit types, which include skarn, greisen, veins, and porphyry deposits, and in orogenic gold deposits as well. The scheelite crystal lattice hosts several trace elements (REE, Mo, Sr, Y, Nb, Na), which provide valuable information about physico-chemical conditions, pathway and source of the hydrothermal ore fluids. Recently, many studies have had focused on understanding the factors that control the incorporation of trace elements into scheelite lattice, and thus using its composition as a discriminant between different types of deposits, focused especially on tungsten skarn-type, and orogenic gold deposits. In this study, we compare the composition of scheelite derived from reduced intrusion-related gold and tungsten skarn-type deposits from the Tombstone-Tungsten Belt (TTB). The goal is to use scheelite as an indicator mineral, not only for tungsten deposits, but also for intrusion-related gold deposits.

The TTB is located at the Northern Canadian Cordillera, between Yukon and Northwest Territories border. Three mid-Cretaceous plutonic suites, from the youngest to the oldest, form the TTB: Tombstone, Mayo and Tungsten. Each suite has distinctive metallogeny that relates to the source and redox conditions of the magmas from which they crystallized. Reduced intrusion-related gold and the tungsten skarn deposits are associated with Mayo and Tungsten suites, respectively. Mayo suite is sub-alkalic, metaluminous to weakly peraluminous, fractionated, contains felsic and mafic components, and moderately reduced. The Tungsten suite peraluminous, felsic, highly fractionated and reduced ilmenite dominant. Both suites share a similar magma oxidation state, which is an important factor in the

formation of ore deposits, as well as a control on the concentrations of trace elements in scheelite.

Scheelite from three reduced intrusion-related gold and from three skarn-type deposits were analysed by EPMA and LA-ICP-MS. Scheelite from reduced intrusion-related gold deposits is constrained to quartz veins, whereas scheelite from tungsten skarn occurs disseminated in different alteration skarn facies (garnet, pyroxene and amphibole/biotite). Cathodoluminescence images reveal that scheelite from reduced intrusion-related gold deposits is homogeneous, whereas scheelite from skarn deposits is variably zoned. Preliminary LA-ICP-MS results reveal that scheelite from reduced intrusion-related gold deposits contains more than 100 ppm of Sr, 1200 ppm Mo in average, and 600 ppm of REE. By contrast, scheelite from tungsten skarn contain less than 100 ppm Sr, and wide range of Mo and REE contents (ranging from 70 to 5000 ppm, and from 50 to 4000 ppm, respectively). Chondrite-normalized REE patterns of scheelite from gold deposits display a negative slope, with positive and negative europium anomalies. However, patterns for scheelite from skarn deposits have three different shapes: i) negative slope, ii) flat, and iii) bell shape, all with mainly negative europium anomalies. Currently, we are working with these data and statistical methods in order to discriminate scheelite from both deposits types.

NORTHWEST TERRITORIES GEOLOGICAL SURVEY GEOPHYSICAL ACTIVITIES, 2019-2020

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The Northwest Territories Geological Survey (NTGS) holds a large collection of government and industry geophysical data and has the mandate to make these data available to the public. The NTGS's online data access systems have been upgraded to simplify client access to this collection. Three new publications are presented and will be available in the near future such as, an updated compilation of airborne geophysical data, geophysical interpretation of Banks Island and a new aeromagnetic survey in the Slave Geological Province.

To aid users in finding available geophysical data, all publically available airborne magnetic, electromagnetic, radiometric, and gravity data conducted in the NWT by federal and territorial governments and industry are represented here on three compilation maps. These finding aids will be published shortly as NTGS Open Report 2019-018.

The Banks Island aeromagnetic data submitted and donated by industry was checked for errors, and enhanced by new interpretive grids. Two compilation maps were produced from the interpretation of all calculated geophysical products of Green River and Parker River areas. The geophysical interpretation is based on a multi-dataset

stacking technique in which the expression of features is compared across various data layers, and features are manually traced. The reduced-to-pole residual magnetic field, first vertical derivative, second vertical derivative, tilt derivative, and analytic signal grids were used during the interpretation process, as input for calculations and as data layers. The goal of this geophysical interpretation of aeromagnetic data is to delineate structures that are potentially prospective for mineralization and identify targets for future work. Several linear or curvilinear features in this aeromagnetic dataset have been interpreted as dykes, faults, and lineaments. One hundred and twenty-six of the best potential kimberlite targets were selected in the Parker River area and seventy-eight in the Green River area. The geophysical interpretation of the Banks Island dataset will be published as NTGS Open File 2019-03.

During the winter of 2019, from February 13th to May 25th, an airborne high-resolution magnetic survey in the Itchen Lake and Point Lake areas was flown for the Northwest Territories Geological Survey by EON Geoscience Inc. The survey area is located in the Slave craton of the Northwest Territories, covering NTS 086H, 086A, and 076E. The nominal traverse line spacing was 100 m with east-west direction and control lines spacing 600 m with north-south direction. The nominal aircraft terrain clearance was 60 m with drape flying. Previous to this study, only low-resolution regional aeromagnetic data was publically available. This new high-resolution aeromagnetic data can be used by multiple stakeholders to enhance geoscience knowledge, promote mineral exploration, and inform land-use planning decisions. The aeromagnetic data of Itchen Lake and Point Lake is published as NTGS Open Report 2019-003.

MIP DOLLARS AT WORK: A PHOTOGRAPHIC RECORD OF EXPLORATORY WORK ON HIGH GRADE GOLD VEINS ON THE AYE AND HANDLE CLAIMS, YELLOWKNIFE, NORTHWEST TERRITORIES, 2014 TO 2017

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Funds provided, in part, under the Individual Prospector Component of the Mineral Incentive Program administered by the Government of the Northwest Territories were used in years 2014 through 2017 to explore high grade gold quartz veins on the AYE and Handle mineral claims located near the south end of Highway 4 within Yellowknife City limits.

Veins range in width generally from 0.10m to 1.5m and are steeply dipping. Country rock is Yellowknife Group mafic volcanics and intrusives with granitic rocks occurring nearby. Faults and shear zones control the emplacement of veins and oreshoots seem to be related to flexures in strike and dip. Mineralization includes fine gold and sparse sulphides. Occasionally visible gold is observed.

Preliminary exploration work included prospecting, cleaning out old trenches dating back to the 1930's and 1940's, mapping and sampling. The best prospects were further tested by shallow diamond drilling, mini-bulk sampling and, in the case of the No.9 vein on

the Handle property, by test mining to a depth of about 1.75m. Metallurgical testing using a standing wave table was performed on 20 kg composite samples of crushed and ground material from the principle orebodies

On the AYE vein an oreshoot 20.0m long, averaging 0.51m wide ran 22.4 g/T (0.65 oz/ton) and the No.9 vein on the Handle claim contained a shoot 10.0m long, averaging 0.30m wide containing 50.7 g/T (1.48 oz/ton) gold. Numerous other gold showings occur on the claims. The Fox vein contains a limited amount of very high grade multi ounce material.

If gold prices reach favourable levels these deposits might be profitably mined on a very small scale.

NEW U-PB AGE DATA FOR BASEMENT GNEISSES AND GRANITOIDS IN THE NONACHO LAKE AREA, NT – CORRELATIONS TO THE QUEEN MAUD BLOCK AND TALTSON BASEMENT COMPLEX

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Directly east of the Taltson magmatic zone in the southwest Rae craton, the ca. 1.91-1.83 Ga Nonacho Group unconformably overlies various gneisses and deformed granitoids. Detrital zircon geochronology of the Nonacho Group has

revealed a spread of Paleoproterozoic to Paleoproterozoic dates that could reflect a protracted history in the local basement. Despite this, the basement remains largely unmapped and unstudied. The age and lithological character of this basement bear on its relationship to the major domains of the western Rae craton (e.g., Queen Maud block, Taltson basement complex) and on the evolution of the craton margin.

This research is focused north-northeast of the main Nonacho basin where basement rocks predominantly comprise amphibolite-facies mafic gneiss, intermediate gneiss with components of granodiorite and diorite, variably deformed granitoids, and locally abundant mafic-ultramafic inclusions. Preliminary U-Pb zircon geochronology indicates that the majority of gneisses and granitoids are younger than typical Neoproterozoic Rae crust. Zircons from mafic components record dates between 2.54-2.35 Ga. Some 2.54-2.45 Ga grains are morphologically and texturally consistent with an igneous origin, whereas a population of homogeneous unzoned grains likely documents ~2.40-2.36 Ga metamorphism. A granodiorite is interpreted to have crystallized ca. 2.50 Ga. Locally preserved biotite-muscovite quartzofeldspathic gneiss is interpreted to be metasedimentary in origin. This unit contains a population of low Th/U (<0.1) zircon rims that may be the product of ~2.48 Ga metamorphism. Approximately 20 km east of the rocks described above, a ca. 2.60 Ga feldspar porphyritic granite occurs that is more typical of Rae crust.

These preliminary age data indicate the presence of rocks previously described from the Rae craton, Queen Maud block and Arrowsmith orogeny. A significant finding is

that the 2.55-2.45 Ga history contains elements of mafic to felsic magmatism and metamorphism that potentially correlate to contemporaneous events in the Queen Maud block.

RECONNAISSANCE SURFICIAL GEOLOGY, LEITH PENINSULA, NORTHWEST TERRITORIES, NTS 86-E

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The Leith Peninsula map area is characterized by three distinct terrain types differentiated by surficial sediment cover and associated landforms. An extensive zone of generally low-lying bedrock-dominated terrain with little sediment cover dominates the eastern regions from Hottah Lake to McTavish Arm. The central and western regions below 280-290 m a.s.l. are covered by various glaciolacustrine sediments, including well developed raised beaches. Arm and McTavish Arm. Minor local variations in ice-flow direction are recorded by striations, crag-and-tail features, and fluted bedrock. Glacial Lake McConnell generally inundated the land in the region up to 290 m a.s.l., and up to 300 m a.s.l. to 305 m a.s.l. in some locations due to local ice configuration.

LONG-TERM STABILITY OF ARSENIC MINERALS IN YELLOWKNIFE BAY SEDIMENTS

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Yellowknife Bay, a northern extension of Great Slave Lake located in the Northwest Territories, Canada, is a waterbody valued by the surrounding communities of Dettah, Ndilo, and Yellowknife for its cultural, subsistence, and recreational uses. Located adjacent to the historical Giant and Con Mines, Yellowknife Bay has received inputs from multiple mine waste streams since the regional onset of gold mining in the late 1930s. A combination of stack emissions, tailings decant discharged via Baker Creek, and direct disposal of Giant Mine tailings has led to pervasive and geochemically complex arsenic contamination in the lacustrine environment. Previous research indicates that arsenic contained in Yellowknife Bay surface waters is elevated relative to Yellowknife River and the main body of Great Slave Lake, albeit within Canadian water quality guidelines for the protection of aquatic life and drinking water. Arsenic contained in sediments associated with peak mining activity is not being buried effectively over time and is mobile in the post-depositional environment, representing a potential sink or source to overlying waters. Investigating the solid-phase speciation of arsenic minerals in Yellowknife Bay sediments will assist in predicting their long-term stability under changing environmental conditions.

During three field seasons (August 2018, March 2019, and July 2019), nine sediment cores were collected proximal to Baker Creek, tailings beach, Ndilo, and Con Mine. Sediment cores were extruded in oxygen reduced conditions and divided for transport to Queen's University in Kingston, ON, and Environment Canada in Ottawa, ON for mineralogical and geochemical analysis, respectively. Samples will have their modal mineralogy determined by scanning electron microscopy (SEM)-based automated mineralogy, and EMPA (Electron Microprobe Analysis) may be used to understand the long-term stability of arsenic solid phases.

WILFRID LAURIER UNIVERSITY: PAST, PRESENT, AND FUTURE RESEARCH IN THE NWT

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For decades, researchers from Wilfrid Laurier University (WLU) have worked in the Northwest Territories, studying various aspects of the environment from multiple disciplines and perspectives. WLU research is closely aligned with government and community priorities and has contributed to the development of evidence-based policy and practical management decisions for both environmental integrity and human health in the territory.

Officially established in 2010, Laurier's longstanding partnership with the Government of the Northwest Territories (GNWT) aims to expand the Territories' capacity to conduct

environmental research and monitoring, and to assist in developing the next leaders needed to manage the NWT's natural resources for future generations. WLU's network of established field sites throughout the NWT, each representing a widely occurring biophysical environment, support field studies that focus on the impacts of a warming climate and human activities on aquatic and terrestrial ecosystems, water resources, food security and communities.

To further assist in enhancing and broadening this partnership and to support our growing capacity for research needs in the NWT, WLU established a research office in downtown Yellowknife in 2017. The goal of Laurier's physical presence in the region is to work more effectively with all GNWT departments, agencies, and communities throughout the NWT in supporting their present and future research needs. The core WLU Yellowknife team includes personnel working on climate, hydrological, permafrost, water quality, and environmental change research with partners across the NWT.

Looking forward, WLU northern research is focused on delivering risk-management solutions to manage water resources throughout Canada where climate change is altering landscapes, ecosystems, and freshwater aquatic and marine environments. This poster presentation includes an overview of the past, present, and future of Laurier research in the NWT, and an introduction to the people who are involved.

THE RELATIONSHIP BETWEEN BARREN-GROUND CARIBOU AND WINTER ROADS

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A number of populations of barren-ground caribou in Northern Canada are declining at alarming rates. Circumpolar declines in *Rangifer* have been attributed in part to increasing levels of human development. Previous research has established a behavioural and distributional response to human activity, including mining infrastructure. In the Northwest Territories, a 14km "zone of influence" (ZOI) around industrial features has been used as the basis for much management and monitoring of barren-ground caribou populations. However, there is still some uncertainty in our understanding of the ZOI for barren-ground caribou and how the ZOI may vary with different disturbance types or seasons. In this research, I am investigating the relationship between barren-ground caribou behaviour, stress physiology, and movement choices and industrial features. The first field season was conducted in February and March 2019 along the Gahcho Kué spur winter road, with a second field season planned for 2020.

Methods for behavioural observation and for assessing stress hormone levels in caribou fecal pellets were successful. The analysis of satellite collar data is ongoing. This project will increase our understanding of ZOI areas adjacent to industrial infrastructure and help wildlife managers and industry refine their monitoring and mitigation efforts for barren-ground caribou in the central Arctic.

PRELIMINARY BEDROCK MAPPING AND LITHOGEOCHEMISTRY OF MAFIC VOLCANIC ROCKS, WINTER LAKE GREENSTONE BELT, SLAVE CRATON

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The Archean Winter Lake greenstone belt (WGB) is located in the western part of the Slave craton ~250 km north-northeast of Yellowknife. Archean volcanic sequences of the Slave craton in the Northwest Territories are highly prospective for base metal mineralization, as several are known to host volcanogenic massive sulfide (VMS) deposits. Despite this, advanced exploration activity is currently focused in Nunavut (e.g., High Lake, Hackett River, IZOK Lake), and therefore prospective volcanic belts in NWT remain under-evaluated for their VMS potential. Part of the challenge in exploring for these deposits is a lack of knowledge regarding their geological setting. This research will aid in understanding the hydrothermal, depositional, and tectonic history of volcanic rocks, which host massive sulfide mineralization in the WGB. A comprehensive study of these massive sulfide mineralization occurrences is timely, since the WGB is adjacent to the proposed Contwoyto all-season road corridor, which could facilitate future exploration efforts.

Previous studies of the mafic volcanic rocks of the WGB resulted in the subdivision into two distinct formations based largely on age; the 3.3-3.1 Ga felsic to intermediate Newbigging Formation and the 2.7-2.6 Ga Snare Formation composed of calc-alkaline and tholeiitic basalts with lesser komatiitic flows. Both formations are extensively intruded by mafic to ultramafic intrusive rocks. Structural interpretations of the WGB have suggested a broadly synclinal architecture but have reached limited conclusions on the relationships between the distinct mafic units or their relationship with adjacent supracrustal formations. The Snare Formation is assumed to be equivalent to tholeiitic mafic volcanic rocks of the 2.7 Ga Kam Group of the Yellowknife greenstone belt, but evidence for this is limited to poorly exposed contacts and a bias towards Yellowknife-centric models in the Slave craton.

Work completed this past summer included detailed mapping (1:2000) of the mafic volcanic rocks of the WGB in three different locations: 1) the south end of Newbigging Lake, 2) the south end of Big Bear Lake, and 3) at a massive sulfide showing roughly half-way between the first two locations. Lithofacies observed at Newbigging Lake included felsic and mafic volcanoclastics with the area being volumetrically dominated by later mafic intrusions. The later two transects at Big Bear Lake and the showing were predominantly composed of pillow basalts with mafic volcanoclastics on the western margins. The upper contact with the younger sedimentary rocks is faulted and the lower contact with the Newbigging Formation is interpreted to be conformable. A rhyolite and a syn-volcanic quartz-bearing gabbro from the Newbigging Lake map area were selected for U-Pb geochronology, while basalts were sampled extensively for whole rock geochemistry and Sm-Nd isotopes to better understand their

petrogenesis. Future work includes detailed lithofacies descriptions of the host rocks and alteration assemblages of the massive sulfide showings to reconstruct the volcanic environment and better constrain volcanic and ore-forming processes.

A PRELIMINARY RE-EVALUATION OF THE NONACHO BASIN, NORTHWEST TERRITORIES, CANADA: MOTIVATING QUESTIONS AND OVERVIEW OF THE 2019 THEMATIC RESEARCH

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The Nonacho Basin has classically been considered a large intracontinental basin formed in a regime of sinistral strike-slip in response to the collision of Rae and Slave cratons at around 1.9 Ga. Strata of the Nonacho Group are sandstone-dominated and have hitherto been related to deposition in a variety of continental settings, including scree slope and alluvial fan to fluvial and lacustrine. Previously published data on provenance is limited to U-Pb dating of detrital zircon from three individual samples; the occurrence therein of an age peak at 1969 Ma corroborates a geodynamic link between generation of the Nonacho Basin and

convergent tectonics along the borders of the Rae Craton. However, poly-phasic folding and associated schistosity, (sub-)greenschist-facies metamorphism, and local development of shear zones have thus far hampered the establishment of a regional provenance framework supported by paleocurrent analysis. In other words, it currently remains unknown whether the detritus deposited in the Nonacho Basin was derived from dismantling of the Thelon-Taltston topographic range or elsewhere. In a broader sense, the lack of paleogeographic constraints on such a large and centrally located basin within the core of the Laurentian plate hampers our full understanding of Paleoproterozoic geodynamics.

To fill such a gap is one of the goals of the Nonacho Bedrock Mapping Project – a multi-disciplinary geoscience initiative led by the Northwest Territories Geological Survey in collaboration with a number of Canadian institutions including Laurentian University. In the summer of 2019, preliminary sedimentologic and stratigraphic investigations were undertaken in the area surrounding Nonacho and MacInnis lakes. Selected units were also sampled for U-Pb dating of detrital zircons. We recognized the originally proposed stratigraphic units of, from the bottom, the Hjalmar, Tronka Chua, Chief Nataway, Newshethdezza, Thekulthili, and Taltson formations. Central to our fieldwork was the detailed bed-by-bed stratigraphic logging and facies analysis of the Tronka Chua and Chief Nataway formations, each of which revealed an abundance of sedimentologic indicators pointing to nearshore-marine – rather than fluvial-lacustrine – deposition, e.g., pervasive wave-ripple cross-lamination, abundant hummocky-cross stratification, and occasional tidal indicators such as bundles and herring-

bone cross-stratification. Ongoing research is currently focused on: refinement of the facies analysis; investigation of potential surfaces of stratigraphic unconformity within the Nonacho Basin; the U-Pb age distribution of detrital zircons from the all the formations in the basin; and the analysis of a dataset of paleocurrent indicators derived from cross-beds in the Tronka Chua, Newshethdezza, Thekulthili, and Taltson formations.

CHARACTERIZATION OF APATITE-HOSTED SILICATE MELT INCLUSIONS IN MAGMATIC ROCKS ASSOCIATED WITH THE CANTUNG (W-CU-AU) SKARN DEPOSIT, NORTHWEST TERRITORIES

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The Cantung (W-Cu-Au) skarn deposit, Northwest Territories, Canada, is one of the most significant high-grade W deposits in the world. The deposit occurs at the contact between Cambrian limestone (Sekwi Formation) of the eastern Selwyn Basin and the Cretaceous Mine Stock Pluton of the Tungsten-Tombstone magmatic belt in the

northern Canadian Cordillera. The Mine Stock pluton consists of a sub-alkaline biotite monzogranite with coeval aplite, pegmatite, and lamprophyre dykes. Reduced W skarn deposits, such as Cantung, form through the interaction of W-rich, low salinity fluids with limestone country rock, producing a zoned array of calc-silicate skarn endowed in scheelite (calcium-tungstate). It has been postulated that the fluids are magmatic in origin and exsolve late in the crystallization of strongly fractionated granitoids. The greatest potential for mineralization occurs when the source magma crystallizes in a deep setting. Slow cooling allows the magma to undergo extensive fractional crystallization and produce an immiscible fluid that is rich in incompatible elements such as W. Mineralizing fluids for Cantung were either derived from the Mine Stock Pluton, or a related magmatic-hydrothermal system at depth, which is now preserved as the late-stage dykes and quartz veins. This study characterizes the apatite-hosted melt inclusions within the Mine Stock, in order to test whether the Mine Stock Pluton is the source of tungsten in the Cantung deposit.

The melt inclusions occur predominately as crystallized (i.e., multi-phase), colorless and transparent inclusions, exhibiting a negative crystal shape, suggesting primary origin. Trace element concentrations of un-homogenized melt inclusions have been determined via laser ablation induced coupled plasma mass spectrometry (LA-ICP-MS). The inclusions have variable compositions, some of which are highly fractionated (Ti/Zr = 1 to 23; Zr/Hf = 1 to 29; n = 60), similar to previously reported whole-rock data for the late stage aplite dykes (Ti/Zr = 3 to 13; Zr/Hf = 8 to 17). The inclusions contain high and variable abundances of incompatible elements such as W (2 to 40 ppm), Sn (27 to 121 ppm), B (100 to 10271 ppm), Cs (10 to 1448

ppm), and Bi (11 to 399 ppm). The W content is an order of magnitude higher than continental crust (~ 1 ppm). Both Au and Cu are below detection limits. Continued work includes homogenization experiments and electron probe microanalysis to quantify major elements abundances and volatiles in the melt. Whole-rock major and trace element abundances of the Mine Stock will also be determined via X-ray fluorescence and ICP-MS. This data will be used to model melt evolution and W-enrichment and determine the crystallinity of the melt at the point of fluid saturation.

ENVIRONMENTAL MONITORING OF PLANNED FOREST HARVEST SITES AND NEARBY PERMAFROST TERRAIN IN THE SOUTHERN NWT

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The Cantung (W-Cu-Au) skarn deposit, Northwest Territories, Canada, is one of the most significant high-grade W deposits in the world. The deposit occurs at the contact

between Cambrian limestone (Sekwi Formation) of the eastern Selwyn Basin and the Cretaceous Mine Stock Pluton of the Tungsten-Tombstone magmatic belt in the northern Canadian Cordillera. The Mine Stock pluton consists of a sub-alkaline biotite monzogranite with coeval aplite, pegmatite, and lamprophyre dykes. Reduced W skarn deposits, such as Cantung, form through the interaction of W-rich, low salinity fluids with limestone country rock, producing a zoned array of calc-silicate skarn endowed in scheelite (calcium-tungstate). It has been postulated that the fluids are magmatic in origin and exsolve late in the crystallization of strongly fractionated granitoids. The greatest potential for mineralization occurs when the source magma crystallizes in a deep setting. Slow cooling allows the magma to undergo extensive fractional crystallization and produce an immiscible fluid that is rich in incompatible elements such as W. Mineralizing fluids for Cantung were either derived from the Mine Stock Pluton, or a related magmatic-hydrothermal system at depth, which is now preserved as the late-stage dykes and quartz veins. This study characterizes the apatite-hosted melt inclusions within the Mine Stock, in order to test whether the Mine Stock Pluton is the source of tungsten in the Cantung deposit.

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TILL GEOCHEMISTRY AND LITHOGEOCHEMICAL EXPLORATION FOR A CONCEALED KIMBERLITE

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Research at the Kelvin kimberlite, NWT, is defining surface exploration practices and testing new host rock lithogeochemical exploration tools that will result in reduced costs and improved discovery success. In regions where recent glaciation has buried kimberlites under glacial sediments, surface geochemical detection methods are best interpreted when coupled with a comprehension of the landscape formation

processes. The glacial, post-glacial, and cryoturbation processes that have affected the landscape have, in turn, affected the dispersal of geochemical signatures in the till that can be detected and exploited by detailed surface mapping, sampling, and geochemical analysis.

The Kelvin kimberlite is an inclined pipe that subcrops from metaturbidite country rock beneath a lake. No indicator mineral train has been detected at Kelvin by traditional indicator mineral methods. Relative uniformity of surficial material (<6m thick till blanket) allows for extensive B horizon soil sampling above the kimberlite, up-ice, and up to 1 km down-ice. Four acid and aqua regia ICP-MS results of the -180 µm fraction indicate the presence of subtle pathfinder element trains originating from the kimberlite subcrop location and extending for >1km down-ice. Dry sonic sieving and four acid digestion results provide interpretations of geochemical partitioning and the ideal size fraction for geochemical sampling. Trace elements demonstrate systematically elevated concentrations in the fine and very fine silt fractions; however, background is higher and anomalous to background contrast is not enhanced compared to bulk -180 µm ratios. Elevated pathfinder concentrations in the fine to very fine sand fraction are attributed to fine kimberlite indicator minerals and their fragments, and display the best anomalous to background contrast ratio. Whole soil commercial Pb isotope analysis of select soils provide supplemental data to fingerprint the petrogenetic source of anomalous samples.

Additional research is being carried out to detect alteration signatures in the country rock induced by the emplacement of the kimberlite. Lithogeochemical data from four drill holes aims to identify and quantify the metasomatic enrichment and depletion of elements sourced from the kimberlite, while hyperspectral imaging will aim to detect secondary mineralogy and subtle changes in mineral

composition. This data will be used to generate mineralogical and geochemical vectors beneficial in near-miss situations when drilling kimberlites and defining diatreme geometries.

could be applied for use in infrastructure, such as along road sections experiencing permafrost degradation.

INFLUENCE OF SNOW COMPACTION ON GROUND TEMPERATURES AT SITES ALONG THE INUVIK- TUKTOYAKTUK HIGHWAY

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Snow cover is a characteristic feature of Arctic regions and is an important factor influencing ground temperatures. Snow is an effective ground insulator, and a decrease or compaction of snow in winter is expected to decrease ground temperatures. The purpose of this field experiment is to examine the influence of snow compaction on the properties of snow, permafrost ground thermal regimes, active layer thickness, and vegetation conditions. Undisturbed and disturbed sites in different terrain types across the treeline along the Inuvik-Tuktoyaktuk Highway corridor will be manipulated by compacting snow several times throughout the winter of 2019/2020. The compactions will be done in partnership with local industry. These manipulation experiments will help to determine whether snow compaction can effectively reduce ground temperatures and stabilize permafrost. Pending experimental outcomes, this method