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GEOLOGICAL SURVEY OF CANADA
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Targeted Geoscience Initiative: list of proposed sub-activities for 2023–2024

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The Targeted Geoscience Initiative

The Targeted Geoscience Initiative (TGI) is a national, collaborative, multidisciplinary geoscience research program of the Geological Survey of Canada (GSC) that aims to improve mineral exploration effectiveness by developing next-generation geological models and knowledge, as well as leading-edge exploration tools and methods to guide exploration in emerging and existing mining areas. First launched in 2000 with the goal of stimulating cost-effective private sector exploration for mineral resources, TGI has continually reoriented its approach to keep pace with scientific advances and the needs of the mineral industry. From an initial focus on characterizing mineral deposits, since 2010 TGI has moved towards understanding the broader mineral systems leading to deposit formation. With ongoing funding of approximately $5M per year and through collaboration with provinces, territories, industry and universities, TGI provides the Canadian mineral industry with next-generation geoscience knowledge, innovative techniques and predictive models to improve effectiveness for targeting buried mineral deposits.

The TGI program supports ongoing government priorities of leading strong economic growth and responsible resource development. The program focuses on providing innovative public geoscience that can be used by the mineral exploration industry to identify and develop mineral deposits in emerging and existing mining areas across the country, which further enhances Canada's reputation as a destination for exploration investment. With enhanced knowledge of how and where mineral deposits formed across Canada, TGI is positioned to develop models that predict mineral potential for Canada's key economic minerals.

TGI Program Objectives

Overarching Program Objective:

- To provide the Canadian mineral industry with the next generation of geoscience knowledge, innovative techniques, and predictive models, which will result in more effective targeting of buried mineral deposits.

Detailed Program Objectives:

- Generate geoscience knowledge to enhance the understanding of the processes that formed Canada's mineral deposits, including critical minerals, and identify and develop novel indicators and parameters to guide exploration in emerging and existing mining areas; and
- Improve mineral exploration effectiveness by developing next-generation geological knowledge, as well as leading edge tools, innovative techniques, and predictive models.

Expected Program Outcomes:

- Development of new knowledge, methodologies and innovative models that enhance exploration industry's ability to detect buried ore deposits;
- Integrated, multi-scale scientific knowledge of source-to-ore formation that guides new exploration approaches;

- Increased pool of highly qualified personnel (HQP) available for employment in the mineral exploration industry;
- Mineral exploration industry can efficiently discover recent and emerging public geoscience knowledge and methodologies relevant to the detection and delineation of new mineral resources; and
- Collaborative geoscience research groups leverage expertise and capacity to effectively solve research questions of pertinence to the exploration industry.

TGI Project and Activity Descriptions (2020 – 2025)

PROJECT 1: ORE SYSTEMS

Project Leader: Bakary Koné

Description: Enhance understanding of Canadian ore deposits, and the larger mineral systems that generate them in suitable geological environments, from metal sources to ore deposition. A system-scale understanding of ore deposits and ore-forming processes is critical to sustain discovery of additional ore resources, either at depth or in remote areas, and reduce risk for companies exploring for ore deposits in Canada. This is essential to secure future supply of critical and economically important minerals in Canada.

Activities

Volcanic, Sedimentary, and Hydrothermal Ore Systems (Activity leader: Jan Peter)

Description: Includes a diverse group of deposits where the primary depositional mechanism is related to dissolution, transport, and deposition of metals by aqueous fluids such as seawater, basinal brines, and groundwater. These fluids are commonly rich in metals and salts and may be super-heated by volcanic activity. These fluids precipitate critical and economically important metals such as zinc, copper, gold, lead, tin, antimony, germanium, bismuth, lithium, and many others. This activity focusses on the physical and chemical processes that lead to leaching, transport and precipitation of economically important elements and minerals from aqueous fluids. The Volcanic, Sedimentary, and Hydrothermal Ore Systems (*sensu lato*) Activity includes deposits primarily related to submarine to subaerial volcanism (and associated subvolcanic plutonism and metasomatism), chemical and clastic sedimentation, and weathering.

Magmatic Ore Systems (Activity leader: Wouter Bleeker)

Description: This research activity will advance the geoscience knowledge of magmatic ore deposits and their fundamental mineral systems by integrating data across all scales, from the deposit to the full magmatic system scale. Magmatic ore deposits form where molten rock (magma) ascends through the crust and either intrudes and cools at depth or is erupted onto Earth's surface forming volcanic edifices. A wide range of processes may lead to concentration of economic minerals, including cooling and crystallization of the magmas, interaction with host rocks, sulfide segregation, magmatic flow segregation, and crystal settling of silicate and oxide minerals. Magmatic systems are compositionally diverse. Mafic (Mg-Fe-rich) magmatic systems are the dominant ore system to generate deposits of nickel, copper, cobalt, platinum, chrome, titanium and vanadium, most of which are considered "critical". Felsic (silica-

rich) or alkaline systems (silica-poor and alkali-rich, including carbonatites) are the dominant host for numerous other minerals and metals ranging from rare metals (Nb, Ta, Zr) and rare earth elements (REE) to battery metals such as lithium. Research will focus on physical and chemical magmatic processes and research outcomes will include improved understanding of how these deposits form, their distribution in space and time across Canada, what localizes them at the system and district scale, and their complete compositional characterization in terms of critical metals.

Orogenic Ore Systems (Activity leader: Sébastien Castonguay)
Description: This research activity will contribute at improving the knowledge of mineral deposits that are formed because of deformation and metamorphism of Earth's crust during orogenesis, with an emphasis on the relationships in space and time to regional tectonic features and their history. Tectonism results in deformation (e.g.,, subsidence, thrusting, faulting, and folding), metamorphism, and plutonism, which can happen at different times and places within an orogenic cycle. These processes can generate magmas and/or hydrothermal fluids that can mobilize and transport metals and focus them into broad corridors with specific areas or discrete zones where precious and critical metals (e.g.,, gold, copper, tellurium and bismuth) are concentrated to form ore deposits. The Orogenic Ore Systems (*sensu lato*) Activity focusses on the drivers and the physical and chemical processes that lead to mobilisation, transport, channelling, and precipitation of economically important elements and minerals from metal-bearing solutions as the crust is deformed, on the traces left by of such processes at ore system to ore zone scale, and on the potential source(s) of metals in orogenic ore systems.

PROJECT 2: DIGITAL GEOSCIENCE AND METHOD DEVELOPMENT

Project Leader: Eric Potter (Acting)
Description: Method development research applicable to multiple ore systems* and/or original research in support of mineral exploration that is not directly related to an ore system.
**Method development research will be included in the Ore Systems Project as much as possible to favour collaboration, complementarity, and shared benefits between ore system knowledge and method development.*

Activities

Machine Learning/Artificial Intelligence Applications /3D Geological/Geophysical Modelling
(Activity leader: Victoria Tschirhart)
Description: Development of: 1) new methods and/or new applications in artificial intelligence (AI) and machine learning (ML) to support exploration for critical and other economically important mineral systems in Canada. Outputs will provide TGI activities, government surveys, industry, academia and the general public with the next generation of ML and AI tools that will allow maximum value extraction from geoscience data; and, 2) geophysical and 3D geological modelling methods to obtain subsurface knowledge of ore systems and enhance the effectiveness of deep exploration. Outcomes will include integrated models of the subsurface constrained by geophysical, geological, petrophysical and geochemical data.

Method Development (Activity leader: Dawn Kellett)
Description: Develop innovative laboratory analytical and data acquisition methods (geology/geophysics/geochemistry/remote sensing) in support of ore systems research. Outputs will

provide the geoscience community and exploration industry with new methods to improve the efficiency and targeting capability of the entire mineral exploration workflow.

Spatial Data Infrastructure (Activity leader: Ernst Schetselaar)
Description: Program-wide digital infrastructure exploiting spatial data infrastructure designs of other GSC programs to: enhance access to TGI's field and laboratory data and derived scientific interpretations; facilitate in-house and external data-driven analysis (e.g.,, statistics, machine learning, modelling); and, meet the demands for open public data dissemination via the internet to industrial, governmental, academic TGI stakeholders and the general public.

TGI Logic Model

Short-Term Outcomes:

- A national program focused on geoscience of critical metals and other economically important mineral systems in Canada with emphasis on effective public data delivery and applications of artificial intelligence.
- Scientific publications and other communications products targeted towards various audiences including decision makers.
- Increased knowledge and understanding of critical metals and other economically important mineral systems in Canada.
- New and improved methods for research in critical metals and other economically important mineral systems, including laboratory, field, archived samples, machine learning and related methods.

Medium-Term Outcomes:

- Enhanced understanding of critical metals and economically important mineral systems in Canada.
- Development of an effective spatial data infrastructure for public dissemination of TGI geoscience data reusable for exploration targeting, mineral potential assessments, 3 -D modelling and machine learning.
- Improved and innovative laboratory, field and analytical methods to support exploring for and advancing understanding of critical and economically important mineral systems, including use of machine learning, artificial intelligence and 3-D visualization.

Long Term Outcomes:

- An innovative mining sector that is globally competitive and environmentally sound across a range of critical and other economically important minerals, by providing world-class geoscience for public good to reduce risk for public and private sector investment decisions.

Outputs:

- Geoscience knowledge products including expert advice, syntheses, data, information, peer-reviewed papers, national mineral potential maps, predictive models, databases, atlases, and tools are developed and made publicly available. Highly qualified personnel are trained and mentored as the next generation of geoscience professionals.

Proposed TGI Sub-Activities (2023 – 2024)

Project 1: Ore Systems

Activity 1.1: Volcanic, Sedimentary, and Hydrothermal Ore Systems

Sub-Activity Title	Principle Investigator	Sub-Activity Descriptions
Metasomatic iron and alkali-calcic systems with iron oxide-copper-gold (IOCG) and critical metal deposits: footprints, endowment, genesis, and prospective settings	Corriveau, Louise	Through internal GSC and external collaborations, the sub-activity will synthesize the metasomatic footprints of representative Canadian metasomatic iron and alkali-calcic (MIAC) systems and their iron oxide copper-gold (IOCG) and affiliated critical and precious metal deposits. It will also provide a new ontology of MIAC systems supported by a field-geology taxonomy and related mappable prospectivity criteria to better prognosticate the mineral potential of Canadian MIAC systems and streamline their mineral exploration at system and deposit scale.
New applications of borehole fluid profiling techniques in support of ore systems research	Crow, Heather	In this research we propose new applications of high-resolution borehole profiling techniques, traditionally used in hydrogeological studies, to provide insights into thermal and chemical properties of borehole fluids as exploration tools. This study is linked with the research being carried out in the Deep Uranium Fluid Pathways sub-activity and supports the investigation of high heat-producing intrusions, faults, and geothermal gradients associated with uranium and REE deposits. Leveraging the GSC's unique outdoor borehole calibration facilities in Ottawa, methods will be developed and tested in collaboration with the University of Guelph, and subsequently deployed to the Athabasca Basin for data acquisition in exploration boreholes.
REE potential of sedimentary phosphorites	Grasby, Stephen	This project will examine REE deposits associated with sedimentary phosphorites in Canada, developing new models on paleo-environmental controls on occurrence. A combined field and laboratory approach will assess resource potential. Results will support new exploration for these critical minerals.
Hydrogeochemical methods for critical metal exploration	Kidder, James	Hydrogeochemistry has the potentially to be a highly effective regional exploration tool in Canada, due to the potential for large dispersion halos and an abundance of surface accessible waters. Despite continued application in many parts of the world, there has been few modern examples of how the method can be applied in Canada. TGI research will improve existing and develop new hydrogeochemical methods for both ground and surface waters through case studies at two critical metal deposits in glaciated and unglaciated terrains. These case studies will demonstrate the efficacy of the method in Canada, particularly with respect to critical metals and transfer these state-of-the-art technologies to the mineral exploration industry.
Indicator mineral chemistry to assess prospectivity for critical metals	McClenaghan, Beth	The proposed research will develop indicator mineral methods that will facilitate exploration for critical metals in Canada. The sub-activity will include detailed mineral chemistry of bedrock samples and surficial sediment samples (case studies) around pegmatites (Li-Cs-Ta) and granitoid-intrusion hosted deposits (Cu-Mo, W-Mo, REE). This proposed research builds on results from the TGI-4 and TGI-5 methods development and indicator mineral studies.
Controls on critical metals in volcanogenic massive sulfide deposits and seafloor massive sulfide modern analogues	Peter, Jan	Volcanogenic massive sulfide (VMS) deposits are a key source of base (Cu, Zn, Pb) and precious metals in Canada. Seafloor massive sulfides (SMS) in the offshore are the modern counterparts to VMS, and there is a recent push to understand their resource potential. Although the base and precious metal contents of both deposit types are generally well known, these deposits can host myriad critical (CM) and other trace (TM) metals and metalloids, but their distribution and genetic controls are poorly

		understood at present. In only a few instances are these "by-product" commodities recovered, largely because of this knowledge gap. This sub-activity will elucidate the distributions and controls of these metals that are of salient importance to the green economy.
Deep uranium fluid pathways	Tschirhart, Victoria	This research project aims to use modern analytical and geophysical methods to examine giant U deposits in the eastern Athabasca Basin and their relationship to deep-seated faults, fluid flow and thermal controls. Through collaboration with GSC staff, industry and academia, we will propose exploration methods for these critical metal systems, while exploring linkages with REE deposits to provide industry with a new predictive exploration model for the enigmatic URU deposit type.
Metagenomics in critical mineral exploration	Kidder, James	Metal-metabolising bacteria are known to proliferate in surface and groundwaters waters and soils around base metal deposits. Ground and stream waters will be sampled around a known metal sulfide deposit and background areas to establish if metagenomics analysis can establish both the microbial species present around mineralization, but also generate relative gradients in abundance. This proof-of-concept study will ascertain if microbial species are traceable in streams and groundwaters draining an undisturbed Mo-W deposit and if this can be used as an exploration vector to new critical metal sources.
Woodstock area sedimentary manganese deposits, geochemistry, geochronology and environmental controls on Mn mineralization	Rogers, Neil	The Woodstock area manganese deposits in southern New Brunswick have the potential to become North America's first producer of 'battery grade' manganese, which is a key component of lithium-ion batteries that are becoming dominant in the electric vehicle market. Currently there is no encompassing model for their genesis, and thus no functional exploration model to predict additional occurrences. By building on recent drilling, and integrating modern analytical data, this sub-activity has the potential to greatly advance knowledge of and support the development of an important resource.
Developing an exploration model for Buckton-type black shale deposits	Grasby, Stephen	Highly anomalous concentrations of precious and base metals approaching economically significant concentrations (Au, Pt, Pd, Ag, Sb, As, Cu, Zn, Cd, Co, Ni, V, Mo, Fe, Mn, Ba, Ca, Br, Se, U, Eu, Ce, La, Lu, Nd, Sm, Tb, Y, Yb) have been identified in Late Cretaceous shales (Second White Specks Formation; 2WS) of Northern Alberta (Dufresne et al., 2001), including the Buckton mineral deposit. The 2WS and equivalent units are widespread, forming potential for critical mineral resources across Alberta, NWT, and Yukon. This project will elucidate processes responsible for mineral enrichment in these black shale units to support development of a new exploration model for this unconventional resource.

Activity 1.2: Magmatic Ore Systems

Sub-Activity Title	Principle Investigator	Sub-Activity Descriptions
Chromite & PGM in Ophiolitic complexes using the Bay of Islands Complex (BOIC) as a natural laboratory	Bédard, Jean	This study will examine the mechanisms generating critical minerals (e.g.,, chromite and Platinum Group Minerals (PGE)) in ophiolitic crust by using existing samples and data from the Bay of Islands Comples (BOIC) of Newfoundland and new targeted geochemical and mineral analyses to generate a georeferenced database. This research will examine geological relationships in the crust, mantle and sole of the BOIC, with a special focus on rocks hosting Cr-PGE minerals; evaluate the genesis and potential economic viability of chromite ore and PGE mineralization in ophiolitic crust; and enhance understanding of key locations of potential mineralization in the BOIC.
Advancing the understanding of the globally significant	Bleeker, Wouter	The Circum-Superior Belt of the Canadian Shield represents one of Canada's main producers of critical minerals. It is also a mineral belt and mineral system of global significance with some of the largest Ni-Cu-Co-PGE sulphide ore deposits in the world, and with much remaining

Circum-Superior mineral system		potential.Although significant progress in understanding has been made in recent years, many key questions pertaining to detailed ore-forming processes and to the regional correlation and extrapolation of the ore-bearing stratigraphy remain, at the belt scale and at larger craton scales. Building on TGI-5 successes, the proposed research aims to resolve many of the key questions, across a range of scales, involving P&T partners across four provinces and one territory, and involving a team of national and international collaborators.
Large mafic and ultramafic magmatic events in the Superior Province: Insights in their critical metals potential	Houlé, Michel	Magnesium and iron-rich magmatic systems are the dominant ore system to host economic accumulations of nickel, copper, cobalt, platinum-group elements, chrome, titanium and vanadium, most of which are considered as “critical metals” for the Canadian economy. The Superior Province in the Canadian Shield is one of the largest and oldest geological provinces, with known emerging districts such as the Ring of Fire (RoF) area in northern Ontario that contains geological resources of critical metals including world-class chrome deposits, significant nickel-copper-cobalt-platinum-group element deposits, and numerous iron- titanium-vanadium prospects. The main goals of this sub-activity are to document and characterize some of the large magmatic events (e.g.,, RoF, Abitibi-Grasset, James Bay) that potentially host world-class magmatic ore systems across the Superior Province.
Carbonatite Rare Metal Mineralization	Kjarsgaard, Bruce	Laboratory experiments, based on existing knowledge of carbonatites, will be undertaken to decipher critical metal (e.g., Nb, REE) source, transport and deposition processes in these rocks. The study encompasses both high temperature carbonatite magmatic deposits (e.g., Nb, P), and low temperature carbonatite fluid- or melt-derived ore deposits (e.g., REE, fluorite). Results will be integrated with field-based studies and carbonatite economic geology compilations to produce a new and revised carbonatite ore-deposit model.
Lithospheric footprints of the Golden Triangle, northwest British Columbia	Lawley, Chris	The Golden Triangle is a remote region of northwest British Columbia containing some of the world's most significant and untapped mineral potential. Most of the 150 past or current mining operations in the Golden Triangle target conventional base- and precious-metal deposits, including gold, silver, and copper. However, the abundance of critical raw materials at these deposits remains mostly unknown and the factors controlling the region's exceptional gold endowment require updated geological models.
Petrology of Ni-Cr-Cu-PGE mineralization in Alaskan-type intrusions	Milidragovic, Dejan	The potential of Alaskan-type intrusions, which are abundant in the northern Cordillera, to host critical metal mineralization (platinum ± iridium-subgroup of platinum group elements) in association with chromite mineralization has been long recognized; these plutonic systems may also contain magmatic sulphide mineralization with high contents of critical and base metals: nickel, copper, rhodium, platinum, and palladium, as well as gold. This research will generate a georeferenced geochemical database of mafic-ultramafic intrusions (i.e. Alaskan-type) in British Columbia (± Yukon) and investigate the physical and geochemical conditions favourable for mineralization. A key goal is to develop relatively inexpensive geochemical criteria to assess the critical metal prospectivity of individual intrusions.
Appalachian Deep Time Machine	Rogers, Neil	The Canadian Appalachians contain multiple generations of overlapping mineralizing events that were generated during progressive accretionary orogenesis, forming a spectrum of ore deposition that is both spatially and temporally heterogeneous, as well as transgressive and diachronous. The Siluro-Devonian, post-orogenic granitoid-related mineralization in particular contain a wide array of critical minerals, including antimony, beryllium, bismuth, copper, fluorite, indium, molybdenum, REE, tin, tungsten and zinc, the distribution of which is genetically linked with the interactions of earlier orogenic events. Constraining the critical processes that localize metal enrichment will be facilitated by linking multiple

		(including new) data sources within a tectonostratigraphic plate reconstruction framework.
Critical minerals within carbonatite, syenite, and allied peralkaline-alkaline rocks in the central and eastern parts of the Canadian Shield: where, when and how were they formed	Sappin, Anne-Aurelie	This sub-activity aims to compile the magmatic rocks of the central and eastern parts of the Canadian Shield which are prospective rocks to host critical mineral resources, like rare earth elements, niobium, and tantalum, to build a comprehensive digital database. New geochronological and geochemical data will also be generated for some of Canada's critical mineral deposits to a better understanding of the overall mineral and magmatic systems. At the same time, we plan to start targeted studies on key critical mineral deposits/occurrences to characterize the physical and chemical magmatic processes involved in the formation of this type of mineralization. All together, these studies will help to understand which critical factors are responsible for the formation of economic critical mineral deposits in Canada, and where they occur in space and time.
Ni-Cu-Co-PGE and other critical metal deposits of North America's 1.1. Ga failed Mid-Continent Rift	Smith, Jennifer	This sub-activity will investigate the tectonic and magmatic controls on ore formation within North America's failed Mid-Continent Rift, with particular focus on the Ni-Cu-Co-PGE mineral system. Geochronology, isotopic, geochemical and geophysical data will be used to improve our understanding of why some intrusions are prospective for Ni-Cu-Co-PGE mineralization while others are not and identify the structural architecture that controls their emplacement. In addition, new geochemical data will be collected to understand the distribution and metallogeny of critical metal deposits throughout the Mid-Continent Rift.
Post-collisional porphyry mineralization in the Cordillera	Zagorevski, Alex	Porphyry deposits contain significant resources of critical and economically important metals and are a major source of revenue in BC and Yukon. Improving the understanding of the porphyry ore systems from a regional perspective will facilitate effective exploration.
REE Mineralization of the Eastern Canadian Shield	Mohammadi, Nadia	The primary objective of this study is to resolve the tectonomagmatic controls on ca. 1460 to 1240 Ma alkaline/peralkaline magmatic systems that developed within the eastern parts of the Canadian Shield (Labrador and adjacent portions of Quebec). These magmatic systems are known to host rare-earth elements (REE) and associated rare-metals (RM: e.g., Zr, Y, Nb, Be, Ta) mineralization. Associated intrusions in this part of the eastern Canadian Shield are also highly prospective for critical mineral resources; however, current metallogenic models are insufficient to provide reliable predictions of REE mineralization on the local or regional scale.

Activity 1.3: Orogenic Ore Systems

Sub-Activity Title	Principle Investigator	Sub-Activity Descriptions
Geological setting and metallogeny of the Detour-Harricana-Turgeon belt and Fenelon deposit, NW Abitibi, Quebec and Ontario	Castonguay, Sébastien	This sub-activity will study the geological setting and gold metallogeny of the poorly exposed but prospective NW part of the Abitibi greenstone belt in Quebec and Ontario. The geology of Detour-Harricana-Turgeon belt, including the Sunday Lake deformation zone, show features similar to the better-studied and well-endowed Timmins and Val-d'Or districts in southern Abitibi. The Fenelon and Martiniere deposits, and the ~25 Moz Detour Lake gold mine, are key sites to acquire new knowledge. The multidisciplinary, multi-scale (belt to deposit) research sub-activity will improve both the geological and exploration models for that under-studied belt, which represents an emerging gold district in northern Abitibi.
Orogenic gold systems of the Canadian Appalachians: Central Newfoundland and beyond	Honsberger, Ian	This sub-activity is investigating the geologic and tectonic settings, indicators, and process controls of emerging, undeveloped and developing, orogenic gold systems in the Canadian Appalachians. Research, which builds upon TGI-5, is elucidating spatial connectivity and process correlations along strike between emerging gold-bearing fault zones. Such information is improving models of Appalachian orogenic gold mineralization that can be

		used to identify new gold occurrences and target the most prospective systems for exploration and potential future development.
Orogenic gold deposits: A closer look at the diversity of types, styles and ages of gold deposits in greenstone belts	Mercier-Langevin, Patrick	The proposed research will address two aspects that were identified as knowledge gaps in gold systems and for which the GSC has the necessary background to contribute to: 1) Multi-scale controls on the development of a diversity of gold deposits types/styles of different ages in greenstone belts, including some "atypical" deposits or settings; and 2) regional- to deposit-scale ore-forming processes in banded iron formation (BIF)-hosted gold deposits. The proposed research will contribute at enhancing our understanding of gold systems at different scales in both mature, but still highly prospective regions, as well as in emerging districts and remote areas, and at generating highly qualified personnel.
Metallogeny of auriferous systems in the Urban-Barry orogenic belt, NE Abitibi Subprovince, Quebec	Pilote, Jean-Luc	This research aims to shed light on the timing and controls on gold and associated metals in the under-explored and under-studied Urban-Barry belt, northern Abitibi. The area is witnessing the development of a world-class gold deposit (Windfall) and yet, our current understanding on the gold metallogeny of the area is minimal. The approach will include extensive field work to improve the stratigraphic and structural evolution model of the belt, which will provide a framework for understanding the timing and genesis of the various styles of gold mineralization in the Urban-Barry belt. This will include using methods such as U-Pb zircon dating, lithogeochemistry, in situ mineral trace element and isotope chemistry, amongst other state-of-the art analytical techniques to unravel the metallogenic nature and evolution of the Urban-Barry belt.
Time-temperature history of faults	Pinet, Nicolas	In several Canadian mining districts, the close spatial association of distinct mineralization types and regional-scale faults indicates variable focussing of hydrothermal ore fluids along long-lived structures in time and/or space. However, field evidence rarely provides a record of the whole history of fault activity (including re-activation episodes and fluid migration events), which hinders efficient targeting of mineralized zones. The sub-activity tackles this knowledge gap through an integrated structural-geochronology-paleo-temperature study of the Grand- Pabos-Restigouche fault system (Gaspé Peninsula, Quebec) and spatially associated mineralized zones.
Huronian Paleoplacer Gold	Rainbird, Rob	Paleoplacer gold deposits, similar to the famous Witwatersrand-type in South Africa, from which about 55% of the gold ever recovered has been sourced, were recently discovered in the Paleoproterozoic Huronian Supergroup within the Cobalt Basin of NE Ontario. These deposits are the first of their type in Canada, so a comprehensive understanding of their depositional setting, genesis and possible broader occurrence is critical for Canada's mining industry and economy.
Innovative thermometric and geochronologic techniques to elucidate the relationships between the world-class Keno Hill Ag-Pb-Zn district, intrusion-related gold mineralization and plutonism	Pinet, Nicolas	Establishing a genetic model for Ag-Pb-Zn veins of the Keno Hill district is hindered by several key knowledge gaps, including the relationship between the mineralization and a causative intrusion and clear geochronological evidence for the contemporaneity of mineralization and magmatism. This activity aims to: 1) document a potential district-scale thermal zonation using clumped isotopes on two common gangue minerals: siderite and calcite, and 2) define the timing of mineralization. From a regional/metallogenic point of view, understanding the relationship between Keno Hill mineralization and igneous body(ies) would allow a better appraisal of the link between polymetallic veins and neighbouring gold deposits. From a methodological point of view, this activity provides the opportunity to test the applicability of clumped isotopes to hydrothermal deposits.
Background metal content in Archean rocks; a study of the influence of volcanic and sedimentary rocks primary composition and	Pilote, Jean-Luc	This research aims to constrain background values for critical, base and precious metals in Archean sedimentary and volcanic rocks and define factors controlling intrinsic primary metal abundances for different rock types. This will provide a geochemical framework from which system-scale metallogenic studies on different styles of mineralization rely on but is

provenance on belt-scale prospectivity	generally poorly established or incomplete due to the low abundances of some elements (i.e., near limits of detection or quantification).

Project 2: Digital Geoscience and Method Development

Activity 2.1: AI and 3D Earth Modelling

Sub-Activity Title	Principle Investigator	Sub-Activity Descriptions
Automatic fracture recognition from borehole photos: methodological developments and geological applications	Pinet, Nicolas	Automatic recognition of geological structures is now a mature application of machine learning, but the results are rarely evaluated critically and independently. The sub-activity aims at automatic fracture recognition from drill box photos and the development of tools to add value to the fracture inventory. The test zone corresponds to the Carlin-type gold zones in the Yukon that were studied during TGI-5.
Ore footprint and vector detection by space based and RPAS hyperspectral	Rogers, Neil	This study will investigate the possibility of using AI analysis of hyperspectral imagery from next generation satellite systems to identify ore footprints reflected by the geobotany of pervasively covered regions. This work will advance prospectivity models/vectoring for critical mineral-rich felsic intrusions, including the Proterozoic, REE-rich, anorogenic granitoids in Labrador. It will also test the utility of hyperspectral analysis deployed by Remotely Piloted Aircraft Systems.
Methods for accurate 3D geological modelling and inference: Uncovering the potential for strategic minerals in the Flin Flon Belt	White, Don	Research will be conducted toward developing novel methods for integrated 3D geological model construction and evaluation. The Flin Flon Belt in Saskatchewan and Manitoba will act as the test-case for this work as it has a prolific history as a base metal producer (including critical minerals) and has one of the most extensive geophysical and drillhole data sets in Canada. Methodologies developed here will be applicable elsewhere in Canada.

Activity 2.2: Method Development

Sub-Activity Title	Principle Investigator	Sub-Activity Descriptions
Unconventional Geochronometry Tools	Davis, Bill and Petts, Duane	The proposed research involves the development of innovative analytical protocols to date minerals directly associated with ore formation. The work will focus on establishing in situ geochronology tools that can provide temporal constraints on the formation of mineral deposits, and ore-forming fluids, and will benefit from the GSC's expertise in geochronology, geochemistry and ore-systems research. Furthermore, the methods developed in this study will be ideally suited to answer a wide range of fundamental research questions in the TGI-6, CMGD and GEM-GeoNorth programs, and will be of great interest to the broader geoscience community.
Detecting Rare Earth Element Minerals in Rocks Using a Field Portable Infrared Spectrometer	Percival, Jeanne	Global demand for critical metals, including rare earth elements (REE), is increasing due to their use in high tech devices, their importance in green and defence technologies and the uncertainty in global supply. Detecting critical metal-bearing minerals is difficult because they occur as accessory phases in a variety of ore deposits and are usually recovered as a secondary product in mining. This project aims to determine how field-portable infrared spectrometers can be used in exploration to rapidly identify critical metal-bearing minerals. Development of field-feasible methodologies should help streamline efforts and shorten timelines from discovery to production.
ID-TIMS development work in support of ore	Wodicka, Natasha	This ID-TIMS development work aims to provide support to TGI ore deposit studies, in particular gold systems research, by helping to improve the

deposit studies: U-Pb geochronology of ore-associated oxide minerals and zircon petrochronology		knowledge of the timing and duration of ore-formation processes and the reconstruction of metallogenic models with high temporal resolution. The study comprises two themes: 1) the ID-TIMS analysis of oxide minerals (e.g., scheelite, cassiterite) to provide precise and direct age constraints on ore mineralization and 2) ID-TIMS zircon petrochronology to constrain the petrogenesis of volcanic and magmatic rocks associated with auriferous systems with great precision and accuracy. In the mid to long term, the new analytical protocols can be applied to other types of ore deposits and could also be beneficial to activities in the Critical Minerals and GEM-GeoNorth programs.
Germanium stable isotopic signatures in sphalerites	Yang, Zhaoping	This sub-activity will conduct innovative analytical method developments in Germanium (Ge) isotope ratio analysis by solution nebulization (SN)- and Laser Ablation (LA)- Multicollection Inductively Coupled Plasma Mass Spectrometry (MC-ICP-MS), and trace element analysis by Triple Quadrupole LA-ICP-MS (LA-ICP-QQQ-MS). These new technologies will then be applied to investigate the Ge isotope and element chemistry of sphalerite, in concert with investigations within the "Volcanic, Sedimentary, and Hydrothermal Ore Systems", and "Orogenic Ore Systems" activities of the Geological Survey of Canada's (GSC) Targeted Geoscience Initiative (TGI) program. The ultimate goal of this research is to apply the integrated Ge isotope and trace element geochemistry of sphalerite as new geochemical probes for (1) advancing understanding of metal sources and enrichment processes that have mobilized, transported and deposited precious, base and critical metals in some of the most important Canadian deposits and districts; (2) developing and/or refining exploration models for Ge-bearing hydrothermal ore systems and orogenic ore systems; (3) distinguishing prospective and least prospective geological environments for Ge-bearing mineral systems, and assessing the prospectivity to host critical metal enrichment for less explored mineral deposits studied within TGI-6 ore system activities. Furthermore, the imperative development of matrix matched sphalerite reference materials for in situ trace element and Ge (S and Pb) isotope ratio analyses by LA-ICP-MS will be beneficial to the entire Ge isotope and LA-ICP-MS analytical community.

Activity 2.3: Spatial Data Infrastructure

Sub-Activity Title	Principle Investigator	Sub-Activity Descriptions
Spatial Data Infrastructure	Schetselaar, Ernst	This activity focuses on developing a program-wide digital infrastructure exploiting spatial data infrastructure designs of other GSC programs to: enhance access to TGI's field and laboratory data and derived scientific interpretations; facilitate in-house and external data-driven analysis (e.g.,, statistics, machine learning, modelling); and, meet the demands for open public data dissemination via the internet to industrial, governmental, academic TGI stakeholders and the general public.
Canadian ThermoCHronology (CATCH)	Powell, Jeremy	This sub-activity will provide Canadians with full digital access to Canada's thermochronological record. To do this we will 1) complete a Canada-wide fully relational database of all low temperature thermochronology data/metadata and associated thermal history models, and 2) compile two decades' worth of 40Ar/39Ar thermochronology interpreted age results for incorporation into a modern Geochronology Laboratory information management system. This initiative will: enhance TGI research by providing easy digital access to all available thermochronology data for Canada; facilitate in-house and external thermal history modelling and machine learning research focused on ore systems for which upper crustal processes and/or structures play a role; take a major step towards meeting demands for open public data availability of geochronology-type data.