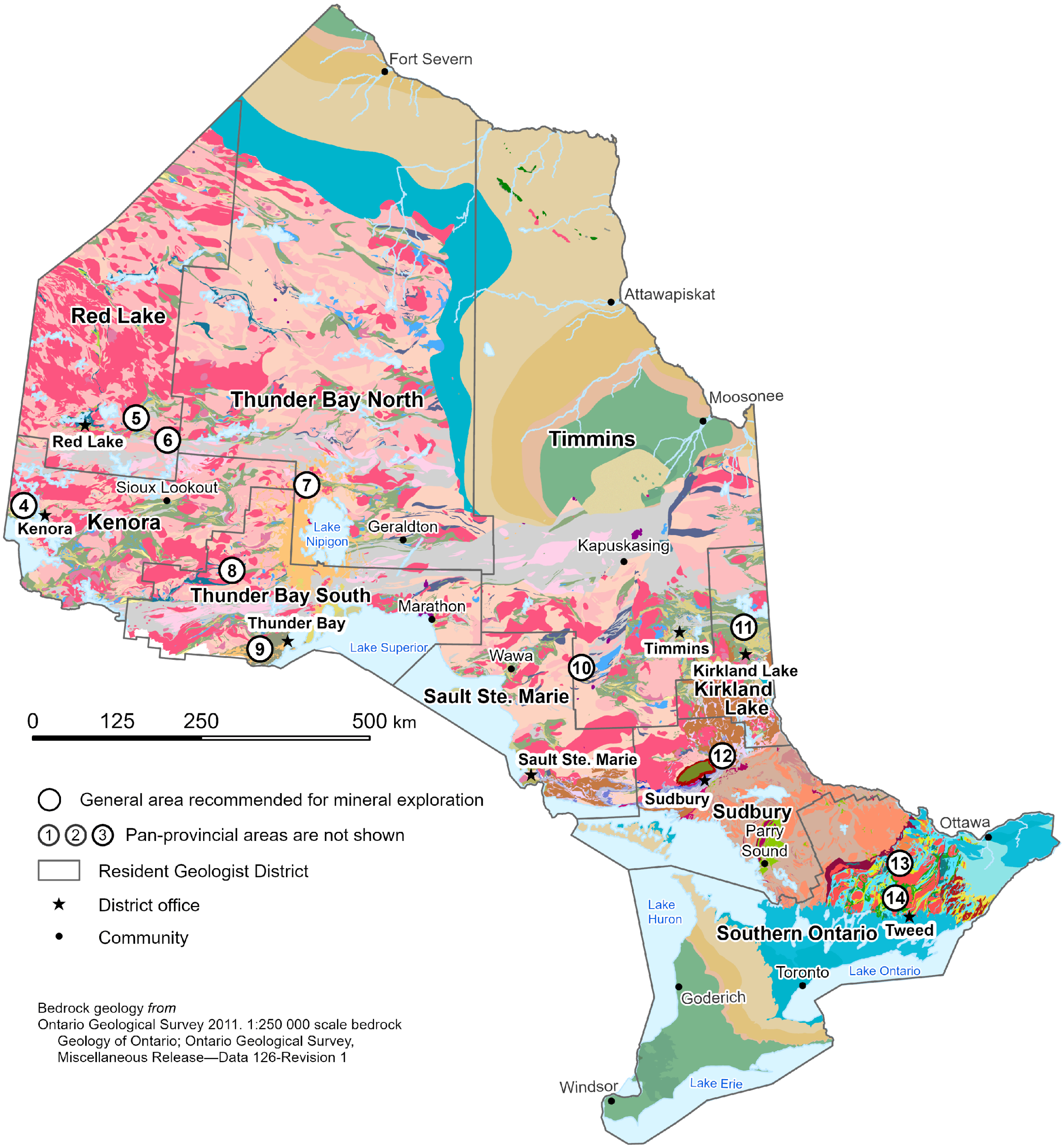
Recommendations for Exploration 2024–2025

Resident Geologist Program | Ontario Geological Survey | Ministry of Mines

ONTARIO CANADA

Ontario

Recommendations for Exploration 2024–2025



Front cover photo:

Mark Puumala (Senior Manager, Resident Geologist Program) examining quartz-diopside-wollastonite gneiss at Canadian Wollastonite's St. Lawrence Deposit, Leeds Township, north of Kingston, Ontario. Credit: Janice Swiercz, Resident Geologist Program.

Ontario Geological Survey
Resident Geologist Program
Recommendations for Exploration 2024–2025

The Ontario Geological Survey (OGS) is pleased to issue its 2024–2025 Recommendations for Exploration. These recommendations have been prepared by the dedicated and knowledgeable staff located in the 8 Resident Geologist Program (RGP) offices across Ontario. They have been developed using existing OGS geological and mineral exploration data, along with new information derived from the current year's activities.

Ontario's diverse geology provides excellent opportunities for mineral exploration and development. This year's recommendations span the entire province and are focussed on a wide variety of deposit types and exploration methods. Targeted mineral deposit types and commodities include the following.

- Mafic–ultramafic intrusion-hosted nickel-copper-platinum group elements
- Mafic intrusion-hosted titanium–vanadium
- Carbonatite-hosted rare earth elements-niobium-phosphate
- Pegmatite-hosted lithium–cesium–tantalum
- Manganese-bearing iron formation
- Lode gold
- Metasomatic iron alkali-calcic (MIAC) copper-gold
- Marble

This year's volume also includes recommendations that highlight how lidar data, biogeochemical surveys, RGP's drill core archives, and Ministry of Mines land tenure information can be used for exploration targeting.

Please review our current Recommendations for Exploration and feel free to discuss these in detail with any of our Resident Geologist Program geoscientists.

Visit GeologyOntario (https://www.hub.geologyontario.mines.gov.on.ca/) and OGSEarth (https://www.geologyontario.mndm.gov.on.ca/ogsearth.html) on the Ministry of Mines Web site to explore the wealth of geoscience and mineral exploration information the Ontario Geological Survey has to offer.

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About the Resident Geologist Program

Resident Geologists are the stewards of public geological and mineral exploration information for their districts. They provide a broad range of advisory services on geological topics of interest to the public, to municipal governments and to the mineral industry.

They are the local experts on why geoscience information is important, what information is available and what is happening in exploration.

The program provides primary client services through a network of 8 field offices strategically located across the province.

Our services include

- collecting and maintaining geological data
- monitoring exploration activity
- conducting property examinations
- providing geological and exploration advice

We provide geoscience information to support

- public safety
- environmental planning
- land use planning
- mineral sector investment and economic development

We provide information and training to First Nation Communities regarding prospecting, mineral exploration and mining.

For more information about the Resident Geologist Program please visit the Mines and Minerals Division Web site at https://www.ontario.ca/page/geology-and-geoscience

Users of OGS products should be aware that Indigenous communities may have Aboriginal or treaty rights or other interests that overlap with areas of mineral potential and exploration.

Published January 2025

Contents

Recommendations for Exploration articles in this volume may also appear in the Resident Geologist Program's *Reports of Activities* for the same year. Readers are advised to consult the associated District *Report of Activities* for any updates and revisions to these recommendations.

Parts of this publication may be quoted if credit is given. It is recommended that reference to this publication be made in the following form:

D'Angelo, V. 2025. Biogeochemical sampling in the Timmins and Sault Ste. Marie Resident Geologist districts; *in* Recommendations for Exploration 2024–2025, Ontario Geological Survey, Resident Geologist Program, p.47-50.

HIGHLIGHTS

- **Mining rights administered in Ontario by MINES via the Mining Act**
- **Patented lands remain significant for exploration purposes due to their origins as mining lands.**
- **June 1 Open List: annual list of the lands or mining rights open for registration, may be located in areas with significant mineral potential**
- **MLAS, AMIS, OMI: resources for prospectors exploring and developing their claims**

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Exploration Opportunities on Former Mining Patents

Land tenure and mining laws in Ontario are administered by the Ministry of Mines under the *Mining Act* and have been amended and supplemented through time. Currently, a prospector can acquire the exclusive right to explore for minerals on a parcel of land in Ontario by registering a mining claim. Exploration can also occur on mining leases, mining patents, and mining licenses of occupation (*see* example in Red Lake area, Figure 1).

Prior to the 1960s, mining patents were commonly issued. The Crown granted these lands with the expectation that the lands would be used for mining purposes. Patents granted the patent holders the right to explore and develop the minerals on the land, as well as the surface rights to perform any activity necessary to do so. The lands can be held by the patent holder for as long as mining taxes are paid. Beginning in the 1960s, mining leases, which have a finite duration, replaced patents as the method of granting mineral rights for mineral production purposes.

Patents are different than claims in that assessment work is not required to keep the land in good standing, nor do they require active exploration as claims do. This translates to large swaths of land with high mineral potential that sit dormant for years with little to no exploration if the patent holder continues to pay the mining taxes. This has led to some patented mining lands being used for other purposes, such as tourism, private residences etc. Despite this, the patented lands remain significant for exploration purposes due to their origins as mining lands.

Every year, patents revert to the Crown through non-payment of mining taxes, resulting in forfeiture or termination of the patents. The Ministry of Mines compiles an annual list of the lands that become open for mining claim registration at 10:00 am EST on June 1, which is published in the Ontario Gazette. A second list comprising lands that may revert to the Crown if mining lands taxes are not paid by December 31 of that year, is published separately, also in the Ontario Gazette. Although forfeiture of these lands is never a sure thing, the list may be worth keeping an eye on.

The reopening and mining land tax arrears lists are accessed through the Mining Lands Administration System (MLAS) Web site under the heading "June 1 open list" at https://www.ontario.ca/page/mining-lands-administration-system.

Many of the newly reverted patents are small, but they may be located in areas with significant mineral potential, and they often occur in groups. Because of the mining related origins of patents, be aware that they may contain abandoned mine hazards that can pose threats to people and

Kurcinka, C.E. 2025. Exploration opportunities on former mining patents; *in* Recommendations for Exploration 2024–2025, Ontario Geological Survey, Resident Geologist Program, p.1-2.

property. Consulting the Abandoned Mines Information System (AMIS) database via the GeologyOntario portal at https://www.hub.geologyontario.mines.gov.on.ca/ is a great initial starting point. Connecting with the local Regional Land Use Geologist or the Mine Hazard Technical Specialist for a more in-depth review of the site could be beneficial. It is also important to be aware of the AMIS disclaimer (https://www.geologyontario.mndm.gov.on.ca/AMIS_Description.html).

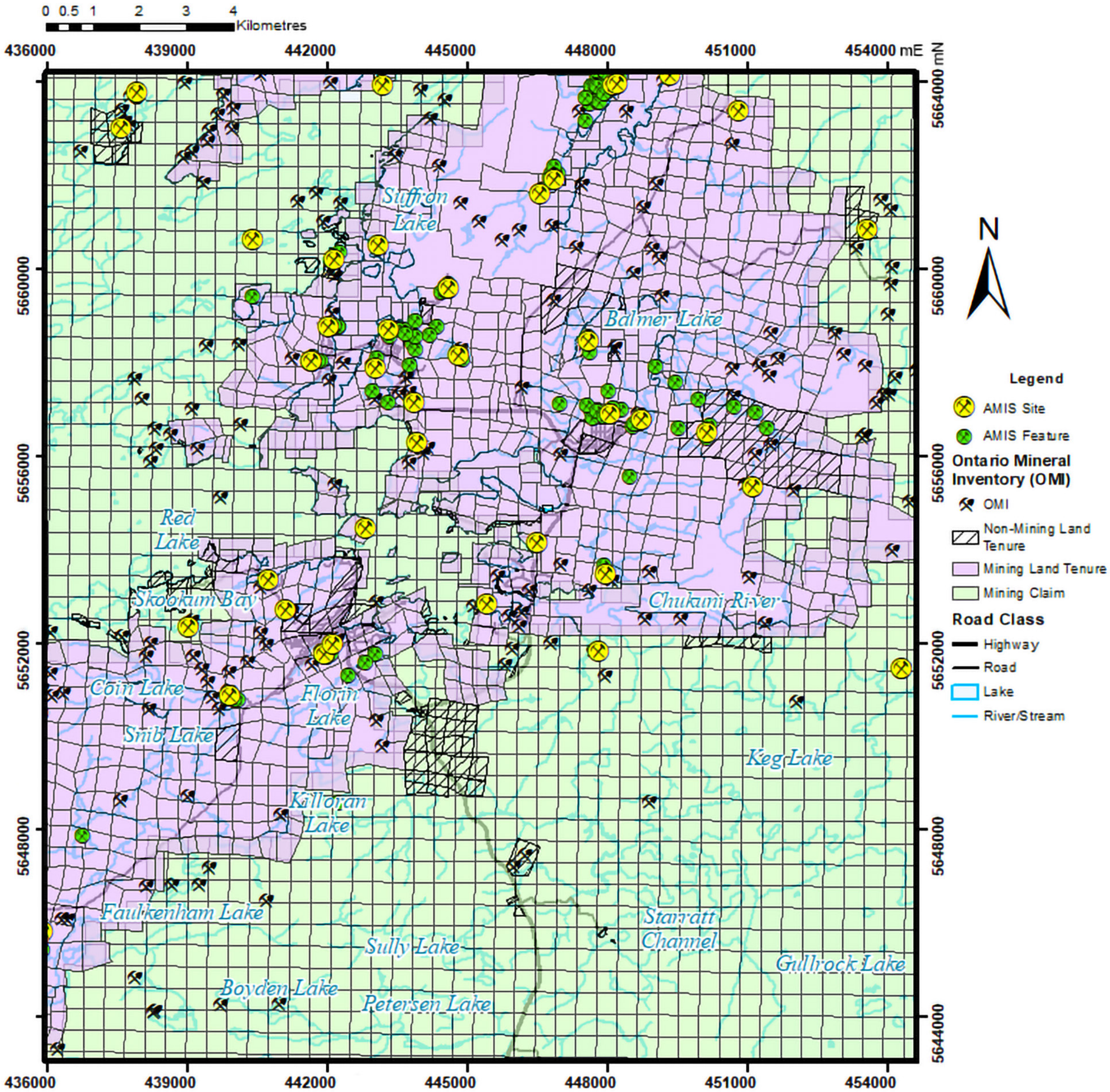

Figure 1. Patents, mining leases and mining licenses of occupation (shown in purple) make up much of the mining district in the Municipality of Red Lake (crossed hammers represent the locations of mineral occurrences documented in the Ontario Mineral Inventory (OMI) database and can be used as a proxy for mineral potential). Sites and locations documenting abandoned mine features in the Abandoned Mines Information System database (AMIS) sites (green and yellow circles with crossed hammers) are found primarily on patented land. Mining claims (shown in green) surround the patents; image *from* MLAS.

HIGHLIGHTS

- **Drill core libraries are an integral part of the cumulative geoscience database that makes the Ontario Geological Survey stand above other geological surveys worldwide and are an asset to Ontario that becomes more valuable over time**
- **Free resource to academia, mineral explorationists and other stakeholders**
- **Storehouse of historic assets in 4 indoor drill core libraries and 9 remote drill core storage sites across the province**

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Resident Geologist Program Drill Core Libraries—A Deep Look Under Your Feet

The value of storing and preserving diamond-drill core has long been recognized by the Ontario Geological Survey (OGS) Resident Geologist Program (RGP). Since the 1960s, diamond-drill core has been collected by staff and/or donated by mineral exploration companies and stored in/near Resident Geologist offices.

The drill core libraries were established with the intent of providing companies access to the drill core to assist their efforts when conducting research, due diligence, and mineral exploration; reducing the costs and time to re-drill, log and sample the core and to assist academic research. The indoor facilities were established by the Ontario Ministry of Natural Resources (MNR) near existing RGP District offices and staffed by a dedicated Drill Core Library Geologist and an Assistant Drill Core Library Geologist, often augmented with contract staff.

The first drill core libraries (DCL) opened in 1984 in Bancroft, Tweed, Swastika/Kirkland Lake, Timmins and Sault Ste. Marie, followed by Thunder Bay and Kenora in 1986. These sites quickly filled with the existing stored core, acquisitions made by staff and through industry donations and/or assessment credit, necessitating telescoping some of the drilled core and cross piling as space permitted.

The year 1993 marked the shutdown of the drill core library program, with all maintenance and responsibilities assumed by the remaining RGP staff and the construction of 6 northwestern remote drill core storage sites (RDCSS). Subsequent RGP office closures and DCL divestures further increased the maintenance and budgetary challenges faced by the ever-shrinking RGP staff to maintain the remaining DCL and now remote/isolated RDCSS facilities.

As of 2024, the OGS currently maintains 4 indoor storage facilities (3 DCLs and 1 warehouse) and 9 RDCSSs (Table 1), with an estimated total of 1 150 000 m of drill core stored in the indoor (~300 000 m) and outdoor (850 000 m) facilities across the province. The DCLs are available for use year-round while the RDCSSs are only seasonal.

Despite the challenges faced by staff shortages, conflicting priorities and budget constraints, the RGP still accepts new core, upon the review and acceptance by the Regional Resident Geologists and District Geologists. When core is donated, the drill logs, and any existing assays/geochemical data are part of the donation requirements. Whenever the drill core in our holdings is re-examined, any data generated is collected as part of the usage agreement and will become available to the public.

Paju, G.P. 2024. Resident Geologist Program drill core libraries—a deep look under your feet; *in* Recommendations for Exploration 2024–2025, Ontario Geological Survey, Resident Geologist Program, p.3-5.

Table 1. Location of drill core storage facilities (DCL and RDCSS) across Ontario.

Location	Facility Type	RGP District
Kirkland Lake (Swastika)	Indoor Drill Core Library	Kirkland Lake
Kenora	Indoor Drill Core Library	Kenora
Thunder Bay	Indoor Drill Core Library	Thunder Bay North/South
Sioux Lookout	Remote Drill Core Storage Site	Kenora
Conmee	Remote Drill Core Storage Site	Thunder Bay North/South
Beardmore	Remote Drill Core Storage Site	Thunder Bay North
Marathon	Remote Drill Core Storage Site	Thunder Bay South
Sault Ste. Marie	Remote Drill Core Storage Site	Sault Ste. Marie
Timmins*	Remote Drill Core Storage Site	Timmins
Kirkland Lake (Swastika)	Remote Drill Core Storage Site	Kirkland Lake
Tweed*	Remote Drill Core Storage Site	Tweed
Red Lake	Remote Drill Core Storage Site	Red Lake
Sudbury**	Off-site Warehouse Storage	Sudbury

**drill core is stored both indoors and outside at the Resident Geologist Program office*
***drill core from both the Resident Geologist Program and the Earth Resources and Geoscience Mapping Section (ERGMS) is stored in the warehouse and maintained by ERGMS*

Despite the challenges posed by overfilled DCLs and RDCSSs and deteriorating core, the drill core holdings of the RGP remain a key and important publicly available resource. In 2023, the RGP facilitated 59 requests for access to the facilities from academic institutions and exploration industry clients, with usage ranging from undergraduate theses to infill sampling as part of mineral resource estimates. The list below is just a snapshot of some projects that have made use of the facilities.

- In 2023, Big Gold Inc. completed an infill sampling program of core stored in the Thunder Bay DCL, allowing them to review historic core and confirm lithology, mineralization, alteration, veining, and structures previously logged. (Big Gold Inc., news releases, December 20, 2023)
- Delta Resources Ltd., relogged and sampled historical core stored in the Thunder Bay DCL related to their Delta-1 gold project. (S.A. Ferguson, Personal Communication)
- The Tweed DCL was used by Dr. J.J. Hanley of Saint Mary's University (Halifax, Nova Scotia) to collect drill core samples for work on a melt inclusion study of the Deloro pluton and links to gold mineralization. The research will involve a collaboration between the University of Boise, Idaho and the University of Geneva. (Mancini et al. 2023)
- L.A. Mancini (Regional Resident Geologist – Tweed) studied and sampled drill core in support of E.C.G. Hastie's (Precambrian Geoscientist, OGS–ERGMS) ongoing research into the gold deposits of Ontario, which is a multi-year collaborative project between the Ontario Geological Survey, the Royal Ontario Museum and the Metal Earth research program. The project is developing a method for analyzing major and trace elements associated with gold and working toward a public database for gold geochemistry across Ontario and the world. (Mancini et al. 2023)
- Metal Energy Corp., examined drill core from 2006 that intersected halite, clay and brine at the Thunder Bay DCL for their SourceRock lithium brine property (*from* Metal Energy Corp., SourceRock project overview [accessed January 30, 2024]).
- In 2023 and 2024 Libra Lithium Corp. tested the various mineralized lithium-bearing pegmatite samples to help calibrate their laser-induced breakdown spectroscopy (LIBS) and build an in-house reference library. (Libra Lithium, personal communication)
- S.V. Churchley (Regional Resident Geologist – Thunder Bay North) is studying the eastern English River subprovince using diamond-drill core donated by Canada Chrome Corp. (formerly KWG Resources Inc.). (Churchley 2024)

- The Geological Survey of Canada has spent several years sampling and studying various intrusions related to the MidContinent Rift through core stored at the Thunder Bay facilities.
- Lakehead University makes use of core from several drill holes for a core logging exercise as part of the Geology Department's 2nd year field school.
- M.A. Puumala (currently Senior Manager – Resident Geologist Program) sampled core for graphitic argillite geochemistry project, which successfully tested a gold targeting method in the Shebandowan greenstone belt (Puumala 2021).

In 2024, the Thunder Bay DCL underwent a complete re-inventory of all drill core stored. This project would not have been possible without the hard work of our summer students Amy Brush, Callie Kok and Logan Pelaia. This will be followed by a re-inventory of the Conmee RDCSS set to commence in 2025, followed by the Beardmore and Marathon sites. Planned inventory of all stored samples in the Thunder Bay DCL is scheduled to commence in 2025–2026.

If you would like to view, or donate any diamond-drill core, please contact the nearest Resident Geologist Program office to where the project is located.

References

Churchley, S.V. 2023. Geology and mineral potential of the eastern English River subprovince, northwestern Ontario: Project introduction; *in* Summary of Field Work and Other Activities, 2023, Ontario Geological Survey, Open File Report 6405, p.37-1 to 37-7.

Mancini, L.A., Dorado-Troughton, M., Swiercz, J., LeBaron, P.S., Hinz, S.L.K., Meyer, G., Sabiri, N. and Fortner, L. 2024. Report of Activities 2023, Resident Geologist Program, Southern Ontario Regional Resident Geologist Report: Southern Ontario District and Petroleum Operations; Ontario Geological Survey, Open File Report 6412, 93p.

Puumala, M.A. 2021. Geochemical data from graphitic metasedimentary rocks of the Shebandowan greenstone belt, northwestern Ontario; Ontario Geological Survey, Miscellaneous Release—Data 391.

HIGHLIGHTS

- **Free publicly available lidar data covering approximately 372 840 km^2 through the Forest Resources Inventory leaf-on program**
- **Lidar's ability to accurately map ground features through vegetation is highly beneficial for mapping programs as potential outcrop and historic workings are clearly defined**

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Ontario Web Raster Services and the Forest Resources Inventory Leaf-on Lidar Data

The Ontario Ministry of Natural Resources Ontario Elevation Mapping Program (OEMP) collects and distributes the airborne lidar (light detection and ranging) data for Ontario, which can be accessed through Ontario GeoHub (https://geohub.lio.gov.on.ca/).

Provincial lidar coverage can be accessed through the Ontario Web Raster Services (OWRS). Publicly available data includes elevation and land cover data from the Ontario Elevation Mapping Program (OEMP) and the Forest Resources Inventory (FRI) Unit. The following data sets are available for download or through the OWRS (Land Information Ontario 2023).

Ontario Elevation Mapping Program Services

- Ontario Digital Terrain Model (Lidar-Derived)
- Ontario Digital Surface Model (Lidar-Derived)
- Ontario Digital Elevation Model (Imagery-Derived)
- Ontario Digital Surface Model (Imagery-Derived)
- Provincial Digital Elevation Model

Forest Resource Inventory Unit Services

- Forest Resource Inventory 2007–2011 Orthophotography
- Available Forest Resource Inventory Term 2 (T2) 2018–2028 Orthophotography and Elevation raster derivatives (CHM, DTM, DSM)
- Ontario Landcover Compilation V.2.0

The Forest Resources Inventory leaf-on lidar data covers approximately 372 840 km^2 of Ontario, extending from the Manitoba border to roughly the northern boundary of Renfrew County (Figure 1). The data set is primarily gathered for mapping vegetation cover, density, and height; however, it also has a representation of the earth's surface, allowing it to be used by other industries.

The leaf-on lidar data set is highly versatile. Users can view the data through the Ontario Web Raster Service or download individual 1 km^2 tiles for specific areas of interest at a 50 cm resolution. The lidar images in Figures 2 to 4 were created using the OWRS in ArcGIS Pro 3.1.0.

Paju, G.F. 2025. Ontario Web Raster Services and the Forest Resources Inventory (FRI) leaf-on lidar data; *in* Recommendations for Exploration 2024–2025, Ontario Geological Survey, Resident Geologist Program, p.6-10.

Figure 1. Coverage of the Forest Resources Inventory leaf-on lidar data sets (Ministry of Natural Resources and Forestry 2022).

Tutorials on how to use the OWRS with the available data sets were created for the following software versions (Land Information Ontario 2023).

- ArcGIS Desktop 10.8.1
- ArcGIS Pro 2.9.3
- QGIS 3.24.1

In the Thunder Bay South District, the Killala Lake alkalic complex (Figure 2A, large red circle) and Prairie Lake carbonatite complex (small red circle) are clearly visible in the lidar data with excellent resolution. These features show a strong correlation to the geological features found on the 1:250 000 scale bedrock geology map of Ontario (Ontario Geological Survey 2011).

In the Thunder Bay North District, the lidar image clearly shows the trenching and pitting (Figure 3; red ellipse) that occurred in 1998 at the Kirby Lake zinc occurrence (MDI42E14SE00004, Ontario Geological Survey 2024) located on the north side of Kirby Lake within the Beardmore–Geraldton greenstone belt. The assessment report filed on the work reported that the trench was approximately 300 ft long and 8 ft wide with the pits ranging from 5 ft by 10 ft to 40 ft by 20 ft (Johansen 1998), matching what can be seen on the lidar imagery.

The past-producing Whitedog aggregate quarry (MDI52L02SW00003, Ontario Geological Survey 2024) in the Kenora District is almost completely obscured by vegetation growth when viewed on satellite imagery, as production ceased in 1958. However, it becomes highly visible with lidar imagery (Figure 4; red ellipse).

Lidar data/image usage among explorationists has been increasing over the last several years. The value of the imagery lies in its ability to enhance structural interpretations of lithological contacts, shear zones, and faults particularly when combined with other geophysical data. Lidar provides highly accurate and detailed mapping of ground features through vegetation, allowing for the clear delineation of potential outcrops, historic workings (such as trenches and pits) and glacial features. This resolution is particularly beneficial for determining up-ice directions, which is crucial for planning till sampling programs.

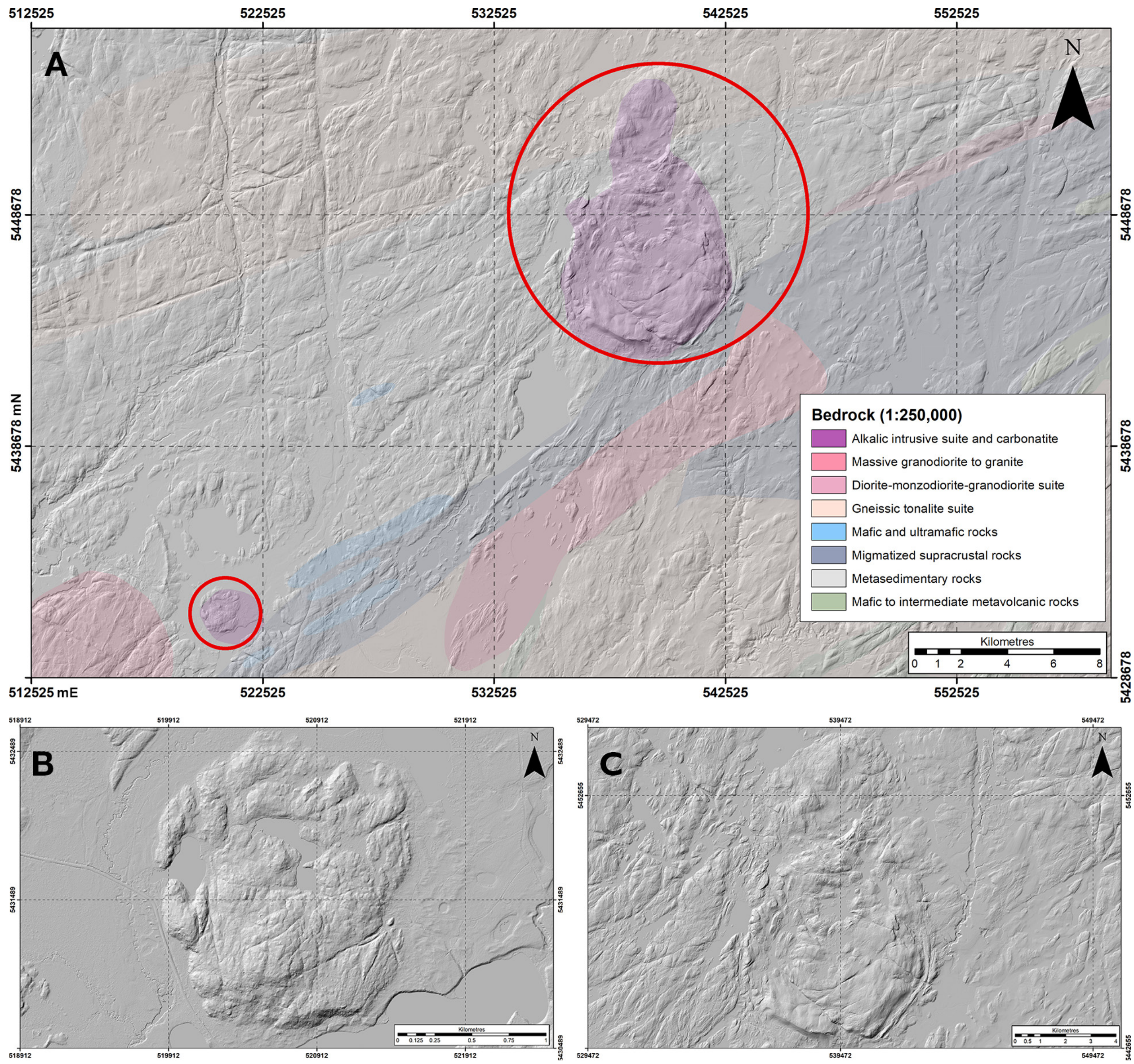

Figure 2. A) Lidar imagery of the Killala Lake alkalic complex (large red circle) and Prairie Lake carbonatite complex (small red circle) overlain by the regional geology. **B)** Close-up of the Prairie Lake carbonatite complex. **C)** Close-up of the Killala Lake alkalic complex. Geology data *from* Ontario Geological Survey (2011); lidar data *from* Forest Resources Inventory (FRI) leaf-on (Ministry of Natural Resources and Forestry 2022); Universal Transverse Mercator (UTM) co-ordinates in North American Datum (NAD83), Zone 16.

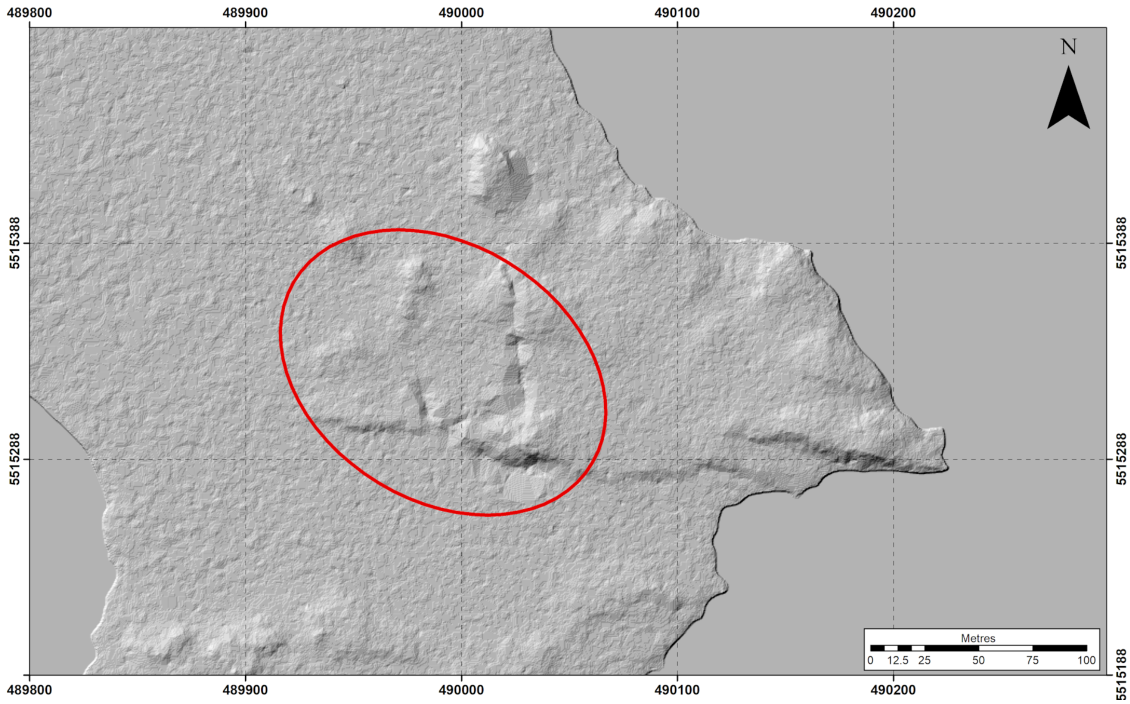

Figure 3. Lidar image showing the pitting and trenching (red ellipse) at the Kirby Lake zinc occurrence. Lidar data *from* Forest Resources Inventory (FRI) leaf-on (Ministry of Natural Resources and Forestry 2022); Universal Transverse Mercator (UTM) co-ordinates in North American Datum (NAD83), Zone 16.

Figure 4. *follows the references.*

References

Johansen, T. 1998. 1998 Work Summary Kirby Lake; Thunder Bay North Resident Geologist's office, assessment file 42E14SE2003, 31p.

Land Information Ontario 2023. Ontario Web Raster Services User Guide; Ministry of Natural Resources and Forestry, Updated February 7, 2023. [accessed October 16, 2024]

Ministry of Natural Resources and Forestry 2022. Forest Resources Inventory leaf-on lidar; Ministry of Natural Resources and Forestry, Science and Research Branch, Forest Resources Information Unit, online data, April 2022 update, https://geohub.lio.gov.on.ca/maps/lio::forest-resources-inventory-leaf-on-lidar/about. [accessed October 16, 2024]

Ontario Geological Survey 2011. 1:250 000 scale bedrock of Ontario; Ontario Geological Survey, Miscellaneous Release—Data 126 - Revison 1.

——— 2024. Ontario Mineral Inventory; Ontario Geological Survey, Ontario Mineral Inventory, online database (October 2024 update).

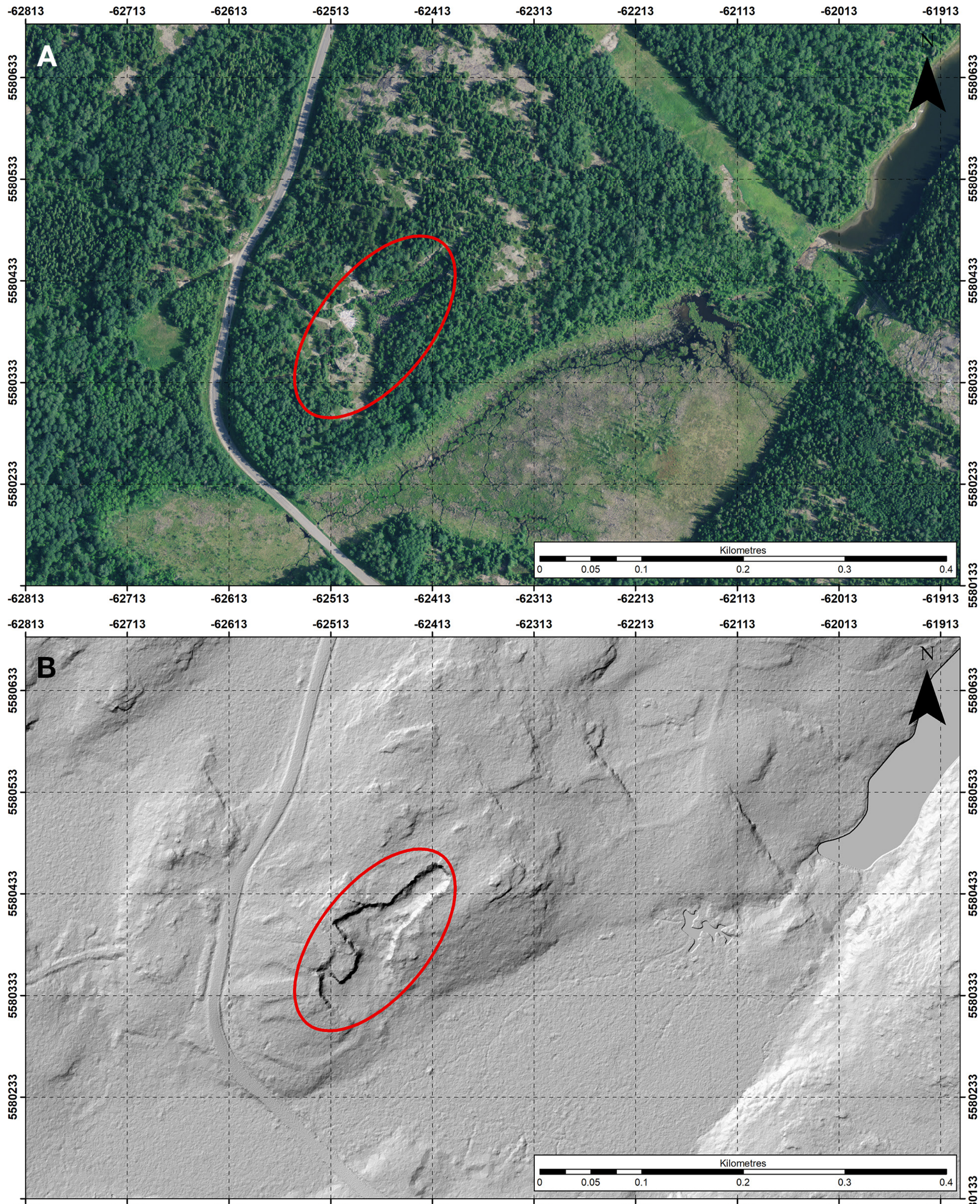

Figure 4. A) Orthophotography and **B)** lidar image showing the Whitedog Quarry (red ellipse). Lidar and orthoimagery *from* Forest Resources Inventory (FRI) leaf-on data sets (Ministry of Natural Resources and Forestry 2022); Universal Transverse Mercator (UTM) co-ordinates in North American Datum (NAD83), Zone 15.

A Ferrocolumbite, Cassiterite and Spessartine Occurrence in the Pelicanpouch Pluton: One and Only or First of Many?

HIGHLIGHTS

- **Mineral occurrence in an unexplored domain characteristic of a lithium-cesium-tantalum pegmatite system**
- **Taylor occurrence discovery of ferrocolumbite, cassiterite and spessartine accessory minerals**
- **Unexplored domain in the Kenora District and open for registration**

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Introduction

Recommended for lithophile element exploration is the vicinity of a recently documented pegmatite-hosted ferrocolumbite, cassiterite and spessartine mineral occurrence, the Taylor occurrence (MDI000000003979, Ontario Geological Survey 2024), as these minerals can be characteristic of a fractionated pegmatite system that host lithium–cesium–tantalum (LCT) mineralization. This occurrence is located within the Pelicanpouch pluton (P3) of the granitoid-dominated Winnipeg River subprovince (WRS), a domain previously considered to have low mineral potential. Currently, the only mineral extraction in the WRS is related to the quarrying of dimension stone and aggregate; however, within the WRS, and particularly in the Lac du Bonnet pluton, there are documented occurrences of pegmatitic lithophile element mineralization in tonalitic rocks near Shatford and Greer Lake (Černý et al. 1981) that are likely related to the voluminous highly fractionated granitoid melts of the Bernic Lake pegmatite group. This article introduces the P3, describes the Taylor occurrence, and closes with an area recommended for follow-up ground reconnaissance based on the alignment of a linear feature in lidar imaging coincident with a series of airborne electromagnetic anomalies. The area recommended for exploration is road accessible and is open for mineral tenure.

Pelicanpouch Pluton

The Pelicanpouch pluton (P3) is an undeformed, unmetamorphosed oblate (~40 km long) composite intrusion of granitoid to ultramafic rocks which intrude into an orthogneissic suite of the WRS (Figure 1; Beakhouse 1991). Granitoid rocks of the P3 range from quartz diorite, tonalite, granodiorite and granite. Mafic portions occur as gabbro-hornblendite blocks and ultramafic rocks occur as small (<20 cm) enclaves. Beakhouse (1983) notes that regionally, the granitoid rocks to the amphibolitic gabbro form a compositional and textural continuum discernable by varying amounts of major rock-forming minerals (e.g., quartz and feldspars) and a progressive change in the color index which decreases toward granodiorite. Age dating of a P3 quartz diorite returned an age of 2700±2 Ma, suggesting the pluton is among the youngest rocks in the WRS (Beakhouse, McNutt and Krogh 1988).

Amyotte, E.G. 2025. A ferrocolumbite, cassiterite and spessartine occurrence in the Pelicanpouch pluton: one and only or first of many?; *in* Recommendations for Exploration 2024–2025, Ontario Geological Survey, Resident Geologist Program, p.11-15.

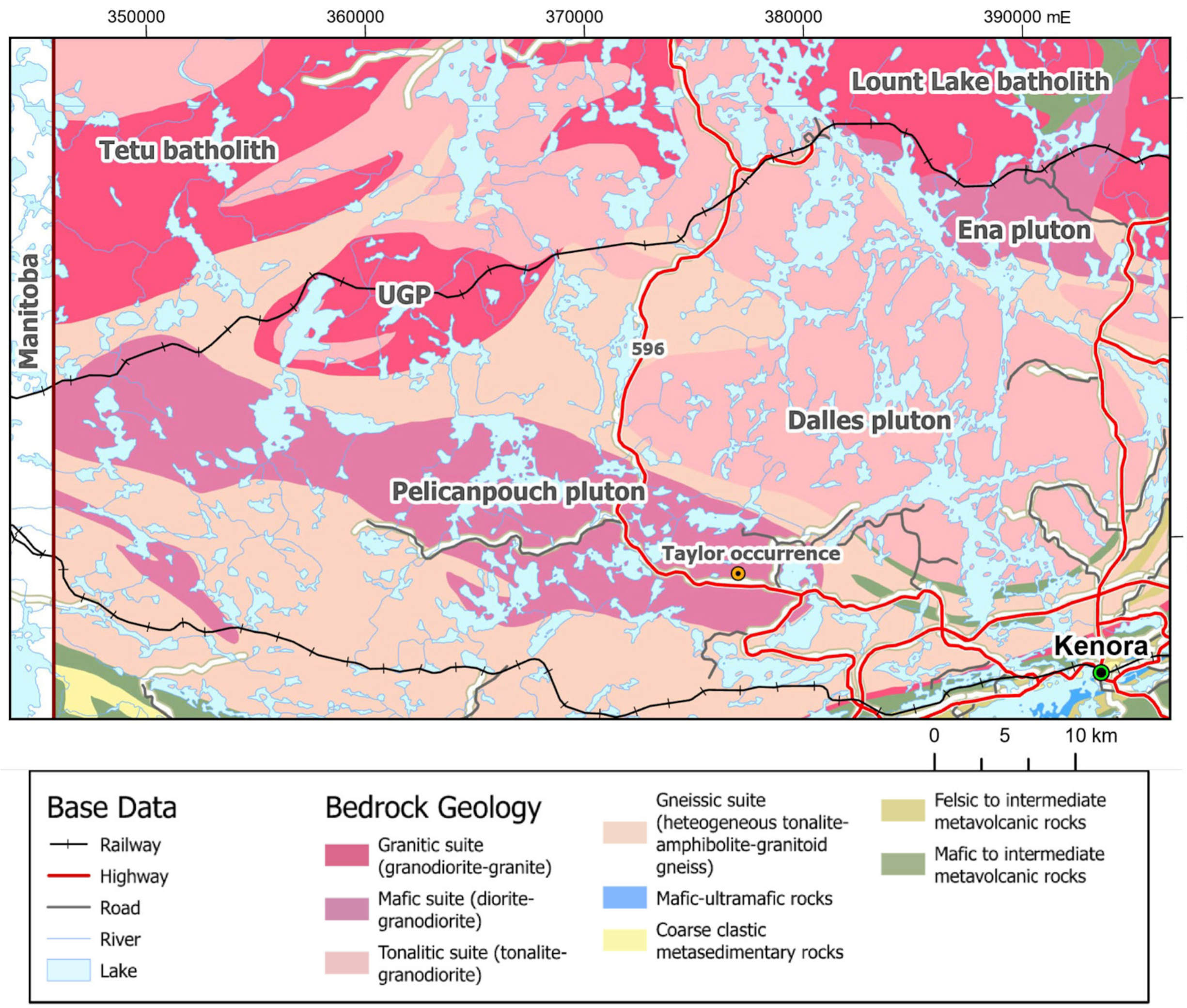

Figure 1. Regional geology map of the Pelicanpouch pluton which illustrates the diversity of Winnipeg River subprovince granitoids north of the Wabigoon subprovince boundary near Kenora (geology *from* Ontario Geological Survey 2011). Abbreviation: UPG, unspecified granite pluton. Universal Transverse Mercator (UTM) co-ordinates in North American Datum (NAD83), Zone 15.

Taylor Occurrence

The Taylor occurrence is a pegmatite with trace ferrocolumbite, cassiterite and spessartine garnet, which are accessory minerals that are associated with LCT pegmatite systems. These minerals were identified by X-ray diffraction and scanning electron microscope instrumentation within a 3 cm elongate, euhedral black mineral which was mainly composed of pyrophanite (pph) and pseudorutile (pdrt). Other minerals present include ulvöspinel (uspl), rutile (rt) and anatase (ant), Photo 1. Additionally, tabulated below is select lithogeochemistry from 2 pegmatite samples collected during a site visit to the occurrence, with sample AT022023 returning a slight rubidium anomaly (Table 1).

The pegmatite itself was identified by Canadian Forces Veteran A. Taylor, who collected the stone on the patented mining claim for ornamental purposes before learning about the increase in lithium pegmatite exploration in the province and requesting a property visit from Kenora District Geologist staff. During the visit, staff noted a moderately exposed (i.e., 70% coverage by thin vegetation or lichens) 1 m wide pegmatite oriented at 230° which

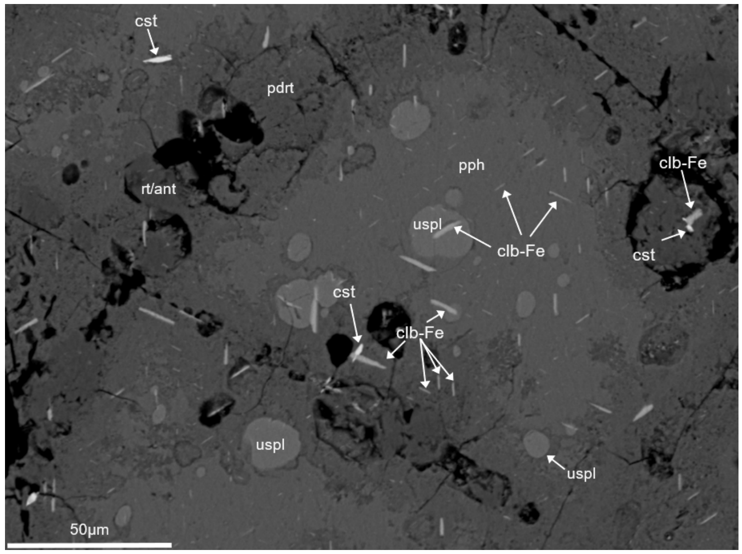

Photo 1. Backscattered electron image showing the mineral phases present within the unidentified black mineral documented in the Taylor occurrence pegmatite. The minerals identified include pyrophanite (pph), pseudorutile (pdrt), ferrocolumbite (clb-Fe), ulvöspinel (uspl), rutile or anatase (rt/ant), cassiterite (cst). Please note: rutile and anatase cannot be differentiated by energy dispersive spectrometry. Image source: Ontario Geological Survey, Geoscience Laboratories (Sudbury), Zeiss EVO-50 tungsten scanning microscope.

Table 1. Select data from ICP–MS multielement and XRF major oxide analysis of the sample from the Taylor occurrence. Sample location: 376518E, 5518984N, Zone 15, NAD 83.

	Multielement analysis ICP–MS (ppm)				Major oxides XFR analysis (wt. %)			
Sample No.	Li	Cs	Ta	Rb	Al_2O_3	Na_2O	K_2O	CaO
AT022023	7.2	9.902	5.317	602.13	16.57	3.26	9.09	0.211
AT032023	23.58	6.249	4.131	264.91	16.48	5.06	4.62	1.173

outcrops over a 400 m strike length and is hosted by quartz diorite of the Pelicanpouch pluton. Bulk mineralogy of the pegmatite is of pinkish potassium feldspar, white plagioclase and clear, white to smokey quartz. Potassium feldspar sometimes displays a perthitic texture, and, to a lesser extent when in contact with smokey quartz, a blocky habit. Plagioclase appears more commonly associated with clear quartz and has graphic texture in places. The quartz occurs mainly as infillings but at least one locality appears compositionally zoned with alternating white to smokey quartz striae (Photo 2). Minor mineralogy includes 1 cm long biotite books, muscovite, and medium-grained subhedral red garnet and magnetite.

Conclusion

Granitoid plutons of the WRS, such as the P3, have seen little historic exploration work, albeit not in the vicinity of significant mineralization typically hosted in an adjacent greenstone belt. The presence of ferrocolumbite, cassiterite and spessartine garnet, as well as a low rubidium anomaly in sample AT02023 in the Taylor occurrence pegmatite, is encouraging for the existence of other similar mineral occurrences and potential LCT pegmatite-related element anomalies which should be used to vector exploration. The explorationist interested in pursuing lithophile element mineralization within the WRS should consider prospecting the area where linear features in the lidar imaging are superimposed by electromagnetic anomalies (*see* Figure 2, Krause 1983). In addition, this area is located near to an unspecified granite pluton (UGP) in the WRS which could be the parental granite responsible for the Taylor mineral occurrence (*see* Figure 1).

Photo 2. Photograph of a pegmatite in outcrop located along the trend of the Taylor occurrence which shows blocky feldspar associated with a striated variety of quartz which alternates between white and smokey. Photo credit: E. Amyotte (2024).

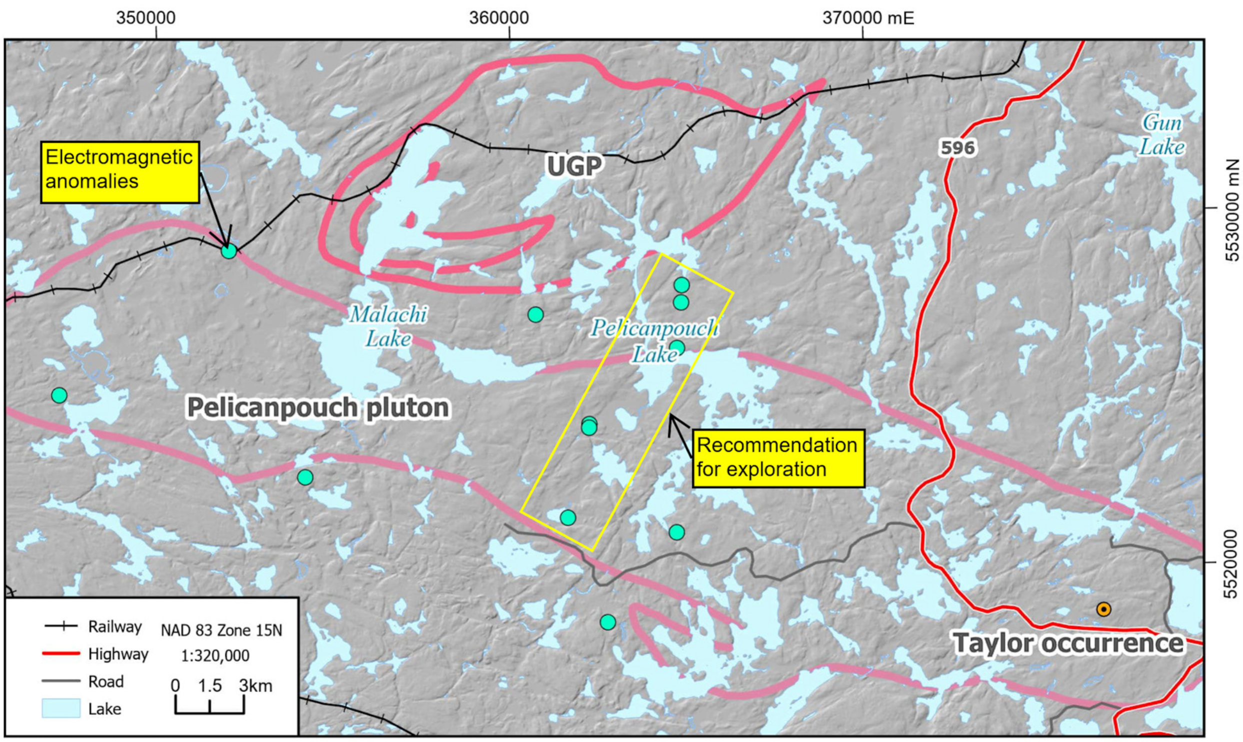

Figure 2. Lidar imagery (Ontario Ministry of Natural Resources and Forestry 2019) overlain by bedrock geology traces (Ontario Geological Survey 2011) and electromagnetic anomalies (Krause 1983). Abbreviation: UPG, unspecified granite pluton.

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HIGHLIGHTS

- **Historically, the area has not been examined for vanadiferous titanomagnetite (VTM) deposits**
- **VTM deposits are the primary source of vanadium**
- **Limited exploration to date in the Red Lake District for VTM deposits, with potential nearby mafic and ultramafic intrusions in the Birch–Uchi greenstone belt**

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Titanium and Vanadium Potential in the Confederation Lake Area

Introduction

Ontario and Canada have listed titanium and vanadium on their critical minerals list (Ontario 2024 and Natural Resources Canada 2024). Titanium has many uses but is primarily used as a white pigment as TiO_2 (e.g., paints, plastic, sunscreen). However, it is also essential as a metal used in aircraft, as titanium is corrosion resistant and has a high strength-to-weight ratio (Woodruff, Bedinger and Piatak 2017). At the same time, vanadium has many uses in making lightweight, high-strength steel, particularly in the aerospace industry. Also, vanadium is becoming ever more important for battery making with some essential characteristics, such as batteries being able to be discharged for a long time and having unlimited capacity (Kelley et al. 2017).

Kelley et al. (2017) provides an excellent overview of vanadiferous titanomagnetite (VTM) deposits as the primary source of vanadium worldwide. Vanadium is typically found within magnetite and ilmenite but to a lesser degree in rutile and hematite, which is why VTM deposits are also rich in titanium and iron. The VTM deposits are primarily associated with mafic and ultramafic intrusions, where magmatic accumulations can be found in large layered tabular bodies or complex intrusive or lens-shaped bodies. Significant vanadium producers include China, Russia and South Africa, while the majority of titanium is produced in China, Australia, South Africa, Canada and Mozambique (Polyak 2024; Gamboji and Tolcin 2024).

Currently in Ontario, the areas with the highest potential have been attributed to the Grenville subprovince, but any mafic and/or ultramafic rocks of Precambrian age have the potential to host VTM deposits (Rogers et al. 1995). As of writing this recommendation for exploration, the Red Lake District has no documented vanadium occurrences, one discretionary occurrence (MDI52M01SE00183) with titanium as a secondary commodity and 12 occurrences with iron as a primary commodity (Ontario Geological Survey 2024). The findings presented in this article describe an area recommended for exploration following a newly discovered occurrence of vanadium and titanium that can be categorized as a primary commodity.

Confederation Lake Occurrence

The occurrence was initially discovered during a property visit on September 20, 2023. During that time, the main goal was to examine a gold property in the Birch–Uchi subprovince, when the staff of the Resident Geologist Program (RGP) came across a magnetite-rich

Malegus, P.M. 2025. Titanium and vanadium potential in the Confederation Lake area; *in* Recommendations for Exploration 2024–2025, Ontario Geological Survey, Resident Geologist Program, p.16-23.

outcrop. Sample 2023PM070 was collected, and the results made it apparent that more work was required from this location. The Red Lake RGP staff then returned to the area on July 5, 2024 to collect additional samples (*see* Table 1) from the same location and others in the area (Figure 1). All analytical data from the samples collected can be found in Tables 2, 3, 4 and 5.

Before heading out for the property visit, OGS map M2498 was consulted. It showed the occurrence area was composed of massive and amygdaloidal flows of mafic metavolcanics, though gabbroic intrusions are mapped nearby (Thurston 1984). Based on the major element data (*see* Table 2), samples 2023PM070, 2024PM014, 2024PM015 and 2024PM016 are potentially mafic as observed by their low SiO_2 and high Fe_2O_3 content. Descriptions for samples 2023PM070, 2024PM014 and 2024PM015 are in Table 1 and all have approximately 50% medium- to coarse-grained magnetite and are the highest-grade samples (Photo 1). Assay results returned for these samples include 3.89 to 8.75% TiO_2 and 1139 to 2639 ppm V, which all qualify as an occurrence based on the Ontario Mineral Inventory mineral deposit criteria (Ontario Geological Survey 2023). Finally, most of these samples returned anomalous values for cobalt, copper and nickel (Table 4).

Based on field observations and major element analysis in Table 2, samples 2024PM017, 2024PM018 and 2024PM019, all sampled south of the occurrence, would appear to be mafic intrusive, possibly gabbro with anomalous titanium and vanadium. Additionally, all the samples returned anomalous values for cobalt, copper and nickel (*see* Table 4), and 2024PM019 returned anomalous values for palladium and platinum (Table 5).

Analytical work was completed on samples 2023PM070, 2024PM014, 2024PM015 and 2024PM016 by SEM and PXRD. Gore (2024a, 2024b) examined all of the samples and noted some common traits in all the samples. Every sample contains coarse-grained magnetite, ilmenite and titanite as main constituents that contain titanium and vanadium, while in 2024PM070, there were inclusions of rutile noted in ilmenite. Other major minerals include chlorite, amphiboles, epidote and quartz in all samples, and no relict olivine/pyroxenes or other minerals to indicate that the rock is ultramafic (Gore 2024a, 2024b).

While titanium is obviously found in titanium-bearing minerals (e.g., ilmenite, titanite and rutile), titanium is also present in all magnetite with values ranging from 1.3 to 3.5 wt. % TiO_2. Vanadium is found in both titanite and magnetite with the following typical values: 0.6 wt. % and 0.3 wt. % V_2O_3, respectively (Gore 2024a, 2024b).

Finally, there is a close spatial relationship between magnetite and ilmenite and titanite, where small euhedral grains of magnetite occur as vermicular intergrowths in ilmenite or entirely replace the original ilmenite crystal (Photo 2). Due to the relationship of this intergrowth noted between ilmenite and both titanite and magnetite, the latter is assumed to have formed due to an oxidizing fluid that altered the original ilmenite (Gore 2024a, 2024b).

Table 1. Location of grab samples all taken from Dent Township with their descriptions.

Sample No.	Easting (m)	Northing (m)	Description
2023PM070	520645.95	5668093	Magnetite-rich, coarse-grained, composed of 40-50% magnetite that is subhedral, homogenous, with possible chlorite within the matrix, trace pyrrhotite
2024PM014	520665.89	5668089.63	Abundant magnetite and 2-3% disseminated pyrite (1-2 mm wide). Heavily oxidized on the weathered face. Light grey-green alteration bands throughout
2024PM015	520665.89	5668089.63	Magnetite-rich, coarse-grained, homogenous magnetite throughout, ~50% magnetite
2024PM016	520665.89	5668089.63	Non-magnetic, fine-grained, wispy carbonate veinlets, dark grey, no mineralization noted
2024PM017	520230.32	5665139.66	The weathered surface is white to tan. White crystals are presumably plagioclase. No mineralization was noted. Medium to coarse grained
2024PM018	520199	5664850.29	Coarse-grained, dark green-black, pyroxene, plagioclase, gabbro, maybe pyroxenite?? ~3% disseminated pyrite
2024PM019	520704.87	5663245.23	Medium grey, coarse-grained leucogabbro could be a diorite, no mineralization was noted

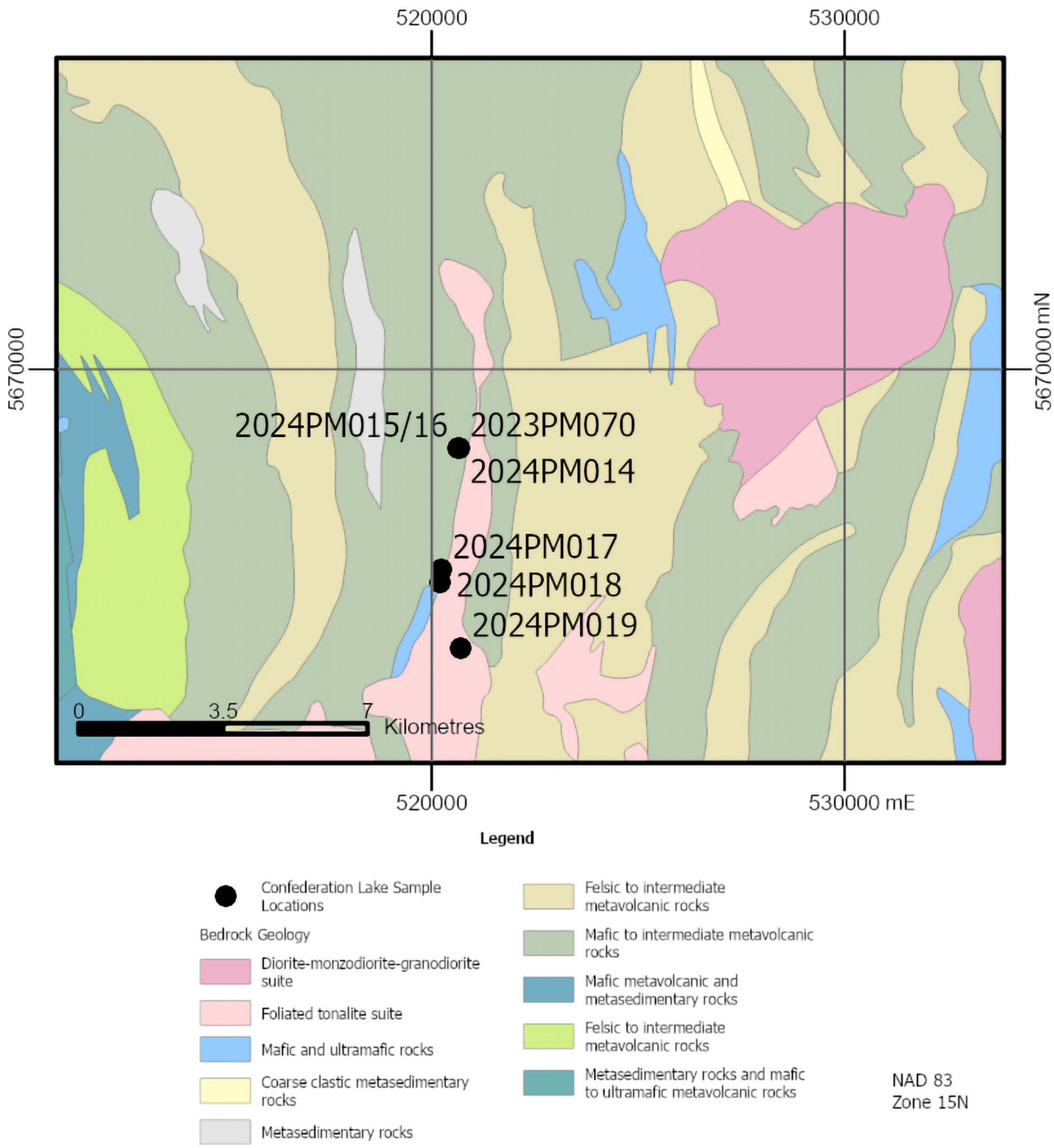

Figure 1. Map showing location of Confederation Lake samples collected in the Birch–Uchi subprovince (*modified from* Ontario Geological Survey 2011).

Table 2. Results of major element analyses (X-ray fluorescence) for samples collected at Confederation Lake. Analyses by Geoscience Laboratories, Ministry of Mines, Sudbury, Ontario.

Sample No.	Al_2O_3	BaO	CaO	Cr_2O_3	Fe_2O_3	K_2O	MgO	MnO
Units	wt. %	wt. %	wt. %	wt. %	wt. %	wt. %	wt. %	wt. %
Detection Limit:	*0.02*	*0.004*	*0.006*	*0.002*	*0.01*	*0.01*	*0.01*	*0.002*
2023PM070	7.06	0.004	5.701	0.026	50.69	0.02	4.84	0.248
2024PM014	10.99	0.005	4.874	0.017	35.53	0.03	7.76	0.252
2024PM015	8.15	0.004	5.455	0.027	47.61	0.03	5.99	0.318
2024PM016	16.36	0.004	5.567	0.055	17.68	0.14	8.83	0.218
2024PM017	12.83	0.006	7.301	0.003	16.16	0.26	3.61	0.257
2024PM018	12.47	0.007	8.059	0.008	23.7	0.71	8.3	0.251
2024PM019	15.9	0.005	10.987	0.13	9.31	0.17	9.99	0.148

Sample No.	MnO	Na_2O	P_2O_5	SiO_2	TiO_2	Total	LOI
Units	wt. %	wt. %	wt. %	wt. %	wt. %	wt. %	wt. %
Detection Limit:	*0.002*	*0.02*	*0.002*	*0.04*	*0.01*		
2023PM070	0.248	0.02	0.063	19.4	8.54	98.71	2.1
2024PM014	0.252	0.06	0.084	33.67	3.89	98.79	4.63
2024PM015	0.318	0.02	0.091	20.33	8.75	99.63	2.87
2024PM016	0.218	1.75	0.018	42.96	0.7	100	5.71
2024PM017	0.257	3.52	0.379	51.28	2.1	99.61	1.91
2024PM018	0.251	0.67	0.028	38.42	2.8	99.52	4.09
2024PM019	0.148	2.21	0.049	47.46	0.55	100.28	3.37

Photo 1. A representative piece of sample 2024PM015, with coarse-grained magnetite present.

Table 3. Results of trace element analyses by inductively coupled plasma mass spectrometry (ICP–MS) for samples collected at Confederation Lake. Analyses by Geoscience Laboratories, Ministry of Mines, Sudbury, Ontario.

Sample No.	Ba	Be	Bi	Cd	Ce	Co	Cr	Cs	Cu	Dy
Units	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Detection Limit:	*1.3*	*0.024*	*0.11*	*0.018*	*0.17*	*0.09*	*2.9*	*0.018*	*0.9*	*0.04*
2023PM070	13.3	0.179	0.11	0.114	4.35	80.62	163.1	0.163	116.2	1.56
2024PM014	45	0.154	0.11	0.134	5.85	125.57	104.8	0.213	376.5	2.4
2024PM015	25.1	0.169	0.11	0.158	5.07	103.42	152.8	0.329	38.8	1.75
2024PM016	33.8	0.139	0.11	0.099	3.27	79.18	374.5	0.127	1.8	1.32
2024PM017	42.6	0.793	0.11	0.119	34.28	30.99	13.8	0.092	41.4	9.03
2024PM018	56.6	0.142	0.11	0.119	3.06	81.6	59.1	1.507	132.3	1.39
2024PM019	36.5	0.338	0.15	0.072	9.55	50.18	915.7	0.095	105	2.3

Sample No.	Er	Eu	Ga	Gd	Hf	Ho	In	La	Li	Lu
Units	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Detection Limit:	*0.04*	*0.008*	*0.04*	*0.04*	*0.09*	*0.006*	*0.0017*	*0.09*	*0.24*	*0.005*
2023PM070	0.99	0.351	18.26	1.34	1.19	0.339	0.0424	1.64	17.93	0.155
2024PM014	1.46	0.561	23.38	2.07	1	0.492	0.075	2.29	23.71	0.206
2024PM015	1.09	0.348	23.78	1.49	1.3	0.368	0.0684	1.97	19.36	0.16
2024PM016	0.76	0.569	26.01	1.22	0.41	0.267	0.0575	1.53	26.5	0.1
2024PM017	5.57	2.211	22.37	8.05	4.07	1.896	0.1561	14.33	4.65	0.787
2024PM018	0.86	0.521	20.43	1.13	0.6	0.297	0.0635	1.4	19.24	0.137
2024PM019	1.36	0.573	14.3	2.19	1.37	0.482	0.0458	4.02	10.74	0.195

Sample No	Mo	Nb	Nd	Ni	Pb	Pr	Rb	Sb	Sc	Sm
Units	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Detection Limit.	*0.08*	*0.05*	*0.11*	*0.6*	*0.29*	*0.019*	*0.15*	*0.025*	*0.17*	*0.05*
2023PM070	0.53	2.79	3.38	289.5	3.97	0.686	0.88	1.887	29.26	1.11
2024PM014	0.27	1.83	4.61	391.8	6.33	0.908	1.22	1.416	44.62	1.52
2024PM015	0.27	3.26	3.881	205.2	4.21	0.809	2.12	2.133	28.06	1.18
2024PM016	0.08	0.28	2.71	217.5	4.95	0.518	2.12	1.682	32.64	0.91
2024PM017	1.13	7.31	23.02	4.7	2.36	4.862	4.07	0.272	33.39	6.59
2024PM018	0.66	1.19	2.45	173.7	4.19	0.45	39.11	0.247	36.49	0.82
2024PM019	0.5	2.23	6.48	184.1	1.87	1.365	3.8	0.905	33.1	1.78

Sample No.	Sn	Sr	Ta	Tb	Te	Th	Ti	Tl	Tm	U
Units	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Detection Limit:	*0.17*	*1.3*	*0.015*	*0.009*	*0.02*	*0.027*	*8*	*0.004*	*0.005*	*0.01*
2023PM070	0.69	35.7	0.186	0.225	0.02	0.184	>46000	0.008	0.145	0.06
2024PM014	0.47	109.2	0.115	0.343	0.06	0.244	21879	0.006	0.202	0.06
2024PM015	0.85	32.4	0.202	0.259	0.02	0.236	>46000	0.009	0.158	0.07
2024PM016	0.3	205.5	0.015	0.197	0.04	0.032	3854	0.01	0.101	0.01
2024PM017	5.12	113.9	0.474	1.36	0.03	1.21	11913	0.017	0.786	0.34
2024PM018	3.61	68.6	0.076	0.203	0.05	0.09	15899	0.128	0.128	0.04
2024PM019	1.9	123.4	0.134	0.359	0.11	0.575	3204	0.018	0.195	0.15

Table 3. *continued.*

Sample No. Units *Detection Limit:*	V ppm *0.4*	W ppm *0.05*	Y ppm *0.09*	Yb ppm *0.008*	Zn ppm *4*	Zr ppm *4*
2023PM070	>580	0.82	8.64	0.981	133	41
2024PM014	>580	0.52	13.05	1.318	189	34
2024PM015	>580	0.75	9.93	1.013	189	46
2024PM016	378.1	0.15	6.97	0.659	229	11
2024PM017	167.7	0.6	51.39	5.177	113	155
2024PM018	>580	0.87	7.77	0.883	200	18
2024PM019	166.9	0.71	13.19	1.291	122	51

Table 4. Results of atomic absorption analyses for samples collected at Confederation Lake. Analyses by Geoscience Laboratories, Ministry of Mines, Sudbury, Ontario.

Sample No. Units *Detection Limit:*	Co ppm *8*	Cu ppm *7*	Ni ppm *16*
2023PM070	-	-	-
2024PM014	137	390	383
2024PM015	112	45	201
2024PM016	85	7	213
2024PM017	34	48	16
2024PM018	89	137	164
2024PM019	54	113	180

Table 5. Results of precious metals analyses by lead fire-assay (with inductively coupled plasma mass spectrometry (ICP–MS) finish) for samples collected at Confederation Lake. Analyses by Geoscience Laboratories, Ministry of Mines, Sudbury, Ontario.

Sample No. Units *Detection Limit:*	Au ppb *0.6*	Pd ppb *0.14*	Pt ppb *0.06*
2023PM070	2.3	2.16	2.17
2024PM014	7.9	7.81	9.68
2024PM015	1.4	0.77	0.40
2024PM016	0.6	9.95	9.62
2024PM017	0.6	0.14	0.14
2024PM018	1.9	0.14	0.14
2024PM019	2.0	52.30	36.70

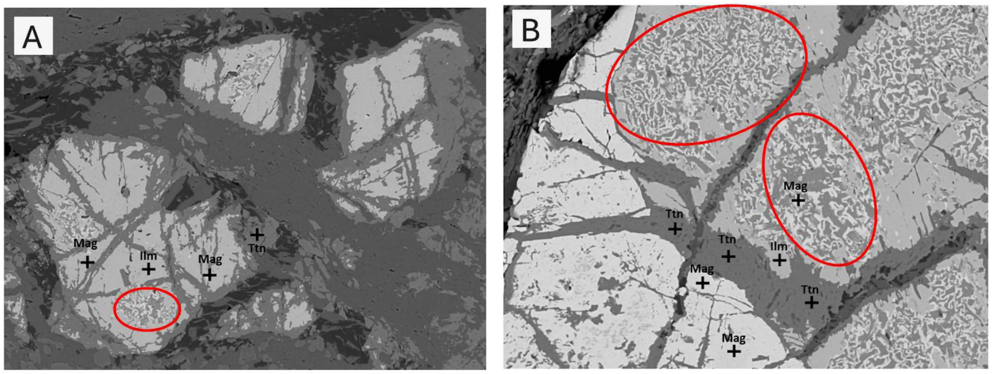

Photo 2. Backscatter electron images (BSEI) of 2024PM014 showing fractured primary grains of ilmenite (Ilm) that are mantled and infilled by titanite (Ttn). Note the vermicular intergrowths (red circles) of titanite and magnetite (Mag) within the ilmenite fragments. **A)** Image field of view scale is 500 µm and **B)** image field of view scale is 250 µm (*modified from* Gore 2024b).

Recommendations for Exploration Tools

The one major geophysical characteristic that can aid in exploring VTM deposits is that they are strongly magnetic. With the mineralization at this occurrence associated with magnetite and also weakly magnetic ilmenite, using publicly available airborne magnetic surveys is a great tool.

For this specific area, Geophysical Data Set 1037—Revised was examined, specifically the total magnetic field and second vertical derivative of the Red Lake–Stormy Lake supergrid data set (Ontario Geological Survey 2017). Highlighted in Figure 2 are the areas specifically recommended for exploration based on the presence of highly magnetic structures, which could indicate mafic and/or ultramafic intrusions. Additionally, Thurston (1984) has several mafic intrusions mapped in the highlighted area.

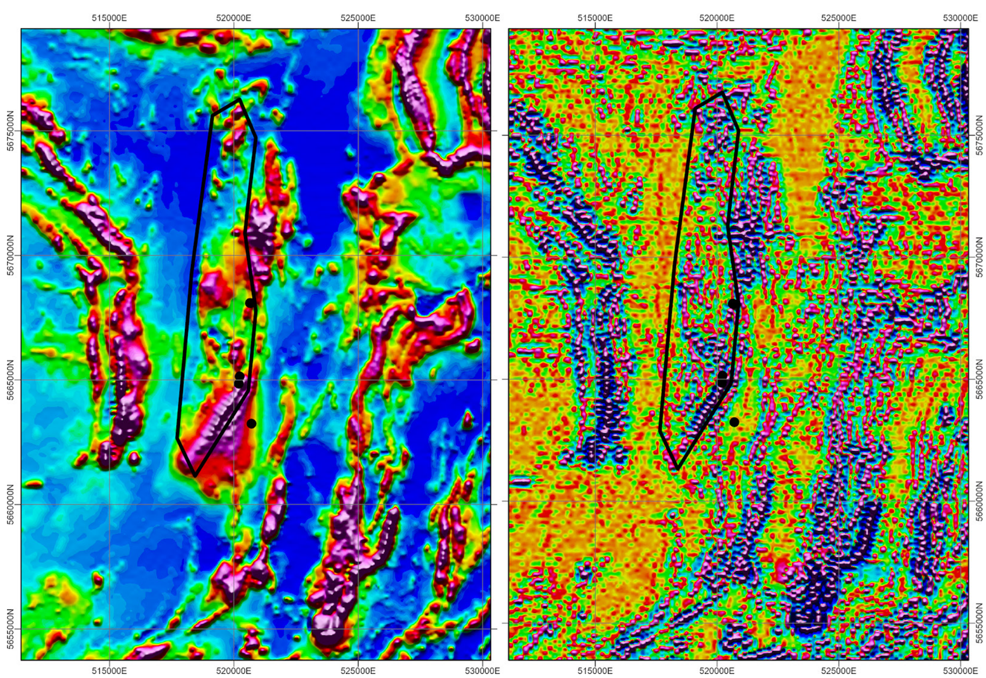

Figure 2. A) The total magnetic field and **B)** second vertical derivative airborne magnetic survey images with a black outline of the areas recommended for exploring VTM mineralization (*modified from* Ontario Geological Survey 2017). Sample locations are noted by black dots, *refer to* Figure 1.

While portions of the area recommended for exploration for VTM mineralization have registered claims at the time of writing, the vast majority of exploration in the area has been for gold. Therefore, there is still ample open ground for exploring and the potential for deals to be made on current claims.

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HIGHLIGHTS

- **Possible carbonatite in the Roadhouse River area, potential to host Nb and REE**
- **Total residual magnetic survey shows anomaly consistent with a carbonatite**
- **Carbonatite potential supported by lake sediment and lake water geochemistry**
- **Additional exploration techniques that confirm a carbonatite include soil, stream sediment and biogeochemical sampling**

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The Case for a Carbonatite, Roadhouse River Area, Red Lake District

Carbonatites are a relatively rare type of intrusive rock with only 527 known occurrences worldwide (Woolley and Kjarsgaard 2008). Distributed across every continent, carbonatites typically occur within stable continental blocks and exploit intracontinental rifts or crustal discontinuities (Verplanck et al. 2014). Commonly, carbonatites exhibit a circular shape in plan view, occurring as pipes, sills, dikes and plugs (Simandl and Paradis 2018). Carbonatites are primary sources of rare earth elements (REE) and niobium (Nb) in addition to a variety of other commodities that have been exploited, including phosphate, fluorite, copper (Cu), iron (Fe), titanium (Ti), vermiculite, calcite and zirconium (Zr) (Verplanck et al. 2014).

At the western margin of the Roadhouse River area, along the Uchi–English River subprovince boundary that is defined in this area by the Lake St. Joseph fault, is a potential carbonatite. North of this potential carbonatite, First Mining Gold reports the occurrence of carbonatite dikes within their Springpole gold deposit (MDI52N08NW00008, Ontario Geological Survey 2024) (Arseneau et al. 2021). The potential carbonatite is along strike from the Root Bay pegmatites to the east and adjacent to discretionary occurrences of beryllium (MDI52K16NE00006, Ontario Geological Survey 2024) and copper (MDI52K16SE00002, Ontario Geological Survey 2024). At the Palabora carbonatite-alkalic complex, copper and iron were mined long before the carbonatite was recognized and REE potential identified (Simandl and Paradis 2018). This shows the potential for carbonatites to occur with or in close proximity to a variety of commodities.

The most useful and often most diagnostic method for identifying the location of a carbonatite is using an aeromagnetic survey. Intrusive deposits, such as carbonatites, are particularly distinct in aeromagnetic surveys (Simandl and Paradis 2018), typically characterized by near circular, anomalous magnetic highs adjacent to anomalous magnetic lows (Puumala and Cundari 2016). Figure 1A shows the aeromagnetic anomaly of a known carbonatite, the Prairie Lake carbonatite-alkalic complex, that occurs in northwestern Ontario and will be used for further comparison in this paper. At the western margin of the Roadhouse River area, there is a magnetic anomaly that appears to fit the characteristics of a carbonatite (Figure 1B). Additionally, Figure 2 shows aeromagnetic maps for several carbonatite-alkalic complexes throughout Ontario and includes a map of the potential carbonatite in the Roadhouse River area (Figure 2A) as well as the Prairie Lake carbonatite-alkalic complex (Figure 2B). The other carbonatites, selected as representative examples

Price, R.L. 2025. The case for a carbonatite, Roadhouse River area, Red Lake District; *in* Recommendations for Exploration 2024–2025, Ontario Geological Survey, Resident Geologist Program, p.24-29.

from across the province include Carb Lake (Figure 2C), Big Beaver House (Figure 2D), Borden (Figure 2E) and Albany Forks (Figure 2F), *see* Satterly (1970). These aeromagnetic maps show variation in the shape of the anomaly, but they all generally have an approximately circular anomalous magnetic high that is “bullseye” shaped with a semi-oval shaped anomalous low at the margin.

Unfortunately, it is common for carbonatites to have little or no outcrop at surface, so traditional mapping methods are not necessarily useful in confirming a carbonatite. Carbonatites are, however, unique in their geochemical composition, as they generally comprise more than 50% primary magmatic carbonate minerals and usually less than 20% silica. Carbonatites are typically enriched in high field strength elements (HFSE), REE, Nb, Zr, tantalum (Ta), thorium (Th) and uranium (U); and large ion lithophile elements (LILE), rubidium (Rb), cesium (Cs), strontium (Sr) and barium (Ba). They are also typically associated with alkalic igneous rocks that will be elevated in sodium (Na) and/or potassium (K) (Verplanck et al. 2014). These unique geochemical characteristics allow for soil sampling, stream sediment sampling, till sampling and water geochemical surveys to be useful in confirming and/or refining the target area.

Lake sediment sampling, which included some water geochemistry, was conducted in the Roadhouse River area in 2000 as well as over the known Prairie Lake complex in 1996. This allowed for a comparison between the known Prairie Lake complex and the potential carbonatite defined by the aeromagnetic anomaly. The calcium (Ca) content in the lake sediments is elevated in the vicinity of both the Prairie Lake complex (Figure 3A) and the potential carbonatite (Figure 3B). This is expected surrounding a carbonatite owing to the high amount of carbonate minerals, most of which contain high proportions of calcium. Carbonate minerals also tend to dissolve when exposed to water, causing the pH to rise and making the water more alkaline. Verplanck et al. (2014) noted the pH of surface water in proximity to a carbonatite to be typically neutral to slightly alkaline. Plotting the pH values of the lakes surrounding both the Prairie Lake carbonatite-alkalic complex (Figure 4A) and the potential carbonatite (Figure 4B), revealed a greater number of lakes that were more alkaline than those in the surrounding rock. Likewise, these carbonatite-alkalic complexes tend to be enriched in sodium and potassium that, when dissolved in water, increase the conductivity. The conductivity of the lake water in the vicinity of both the Prairie Lake complex (Figure 5A) and the potential carbonatite (Figure 5B) exhibited elevated values.

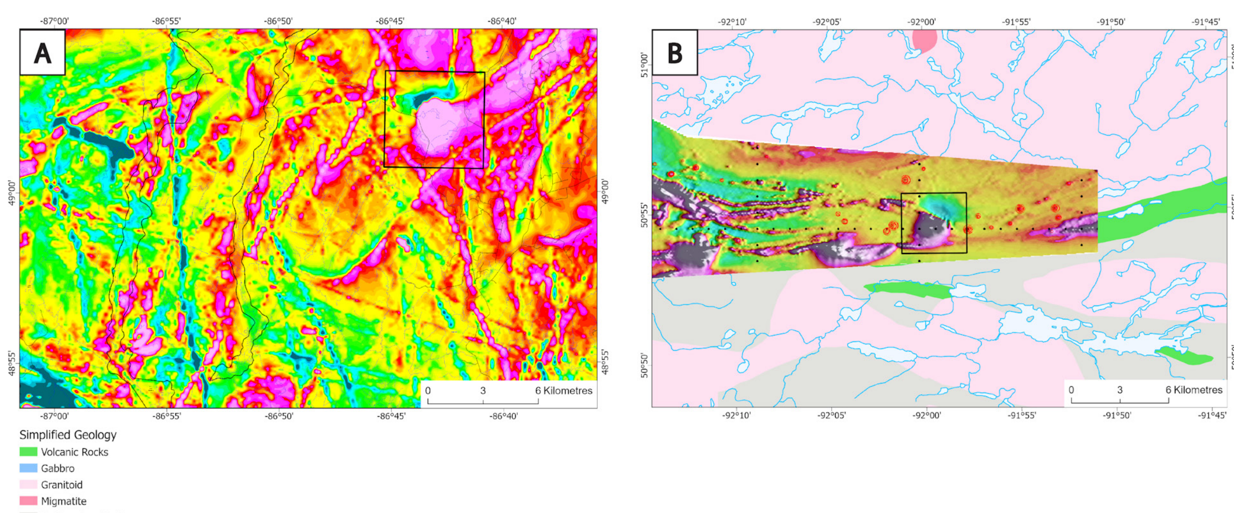

Figure 1. A) Total residual magnetic field image of the Schreiber area showing the near circular anomalous magnetic high and adjacent anomalous magnetic low that defines the Prairie Lake carbonatite-alkalic complex (Ontario Geological Survey 2003b). **B)** Total residual magnetic field image overlying the bedrock geology of the Uchi–Bruce Lakes area showing the approximately circular anomalous magnetic high and adjacent anomalous magnetic low at the western margin of the Roadhouse River area (Ontario Geological Survey 2003a). Geology *modified from* Ontario Geological Survey (2011).

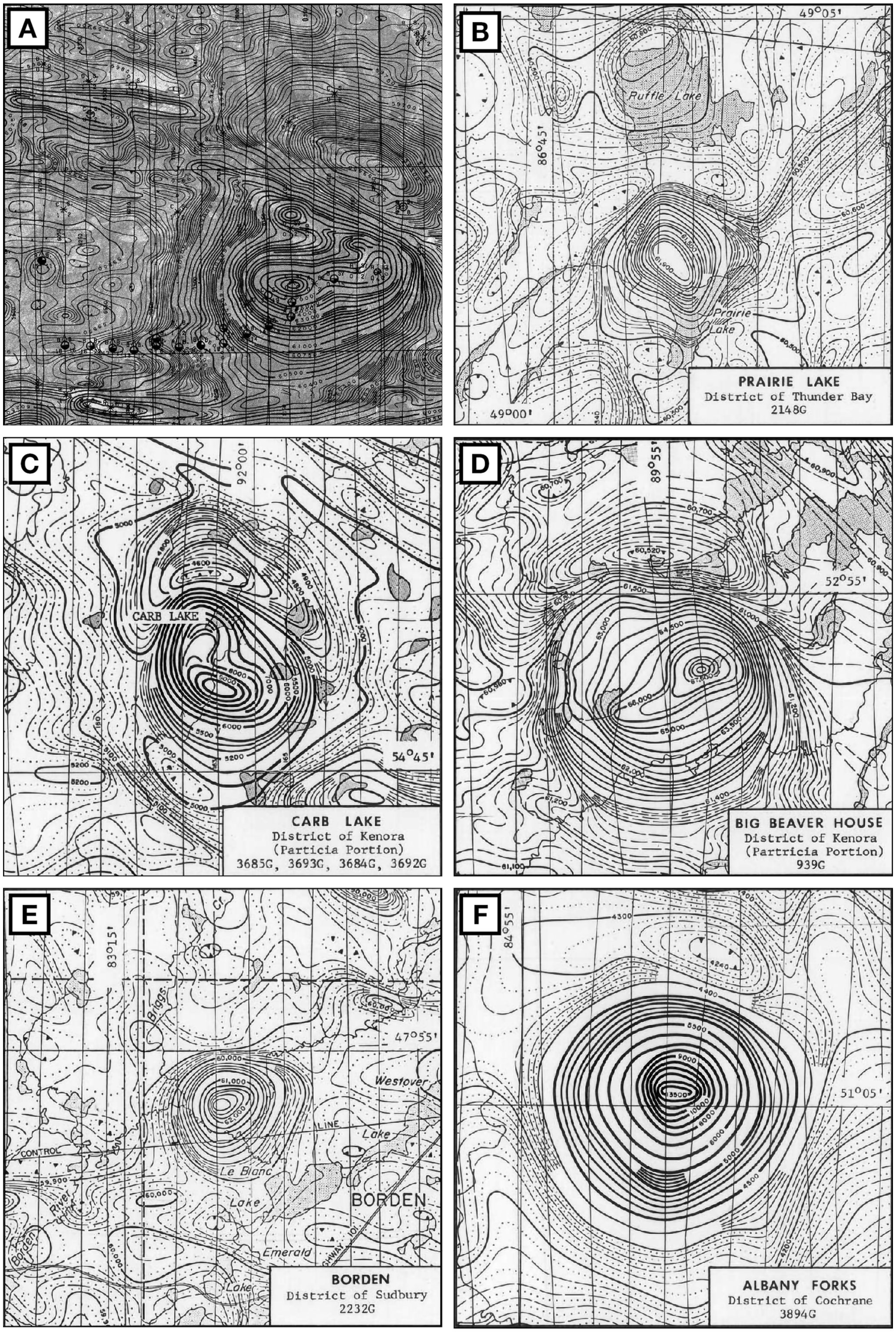

Figure 2. Aeromagnetic maps of carbonatite-alkalic complexes in Ontario (2A to 2F, *modified from* Satterly 1970). **A)** Total intensity magnetic survey of the potential carbonatite in the Roadhouse River area (*modified from* Ontario Geological Survey 1991). Aeromagnetic maps of the **B)** Prairie Lake carbonatite-alkalic complex, **C)** Carb Lake carbonatite, **D)** Big Beaver House carbonatite, **E)** Borden carbonatite, and **F)** Albany Forks carbonatite.

Additional surveys, such as till, stream sediment and soil sampling, would be useful in confirming a carbonatite. Kunzendorf and Secher (1987) completed soil sampling of the A1 horizon in West Greenland and noted both depletion and enrichment in elements that are expected to be elevated in carbonatites. The enriched major elements included SiO_2, TiO_2, Al_2O_3, Fe_2O_3 and P_2O_5 with depletions in CaO and K_2O. Likewise, enrichment in the trace elements Cu, Rb, Zn and Zr with depletions in Sr and U were noted. They commented that it was important to understand the behaviour of the elements when doing soil sampling as this will strongly influence whether an element is elevated or depleted. Niobium and REE mineralization (pyrochlore, columbite, fersmite, monazite and the REE fluorocarbonates) tend to separate into the heavy faction during gravity separation (Simandl and Paradis 2018). This makes stream sediment sampling a useful technique, particularly for determining the REE and Nb mineralization content (Ahn et al. 2014). Niobium, which commonly occurs in pyrochlore, can be mechanically transported, thus enrichment or depletion is strongly controlled by the environment (Kunzendorf and Secher 1987). MacKay et al. (2016) showed carbonatite-related niobium mineralization detected more than 11 km downstream of a deposit. Carbonatites are commonly enriched in the light rare earth elements (LREE), and a similar pattern is expected to be produced in the stream sediments if a carbonatite is present (Ahn et al. 2014). Apatite could also be used as an indicator mineral for carbonatites either in stream sediments or glacial till samples (MacKay et al. 2016). Chakhmouradian et al. (2017) discuss the distinct compositional variation and element partitioning that is unique to carbonatites and makes it easy to distinguish between carbonatitic apatite and typical igneous apatite. Owing to their distinct chemical composition, carbonatites can largely influence the ecological environment (Simandl and Paradis 2018). This has led some researchers to suggest biogeochemical methods to confirm or refine the target of exploration for carbonatites (Vestin et al. 2006; Simandl and Paradis 2018).

The data presented supports the presence of a carbonatite but additional work and ultimately drilling is required to confirm. High resolution aeromagnetic surveys do not cover all of Ontario but are useful in revealing additional carbonatite targets. Their potential to host niobium and REE mineralization, which will be needed in an electrified future, should not be overlooked. Being able to identify carbonatite mineralization when conducting soil, till, and sediment sampling means it can be a secondary target during most exploration programs.

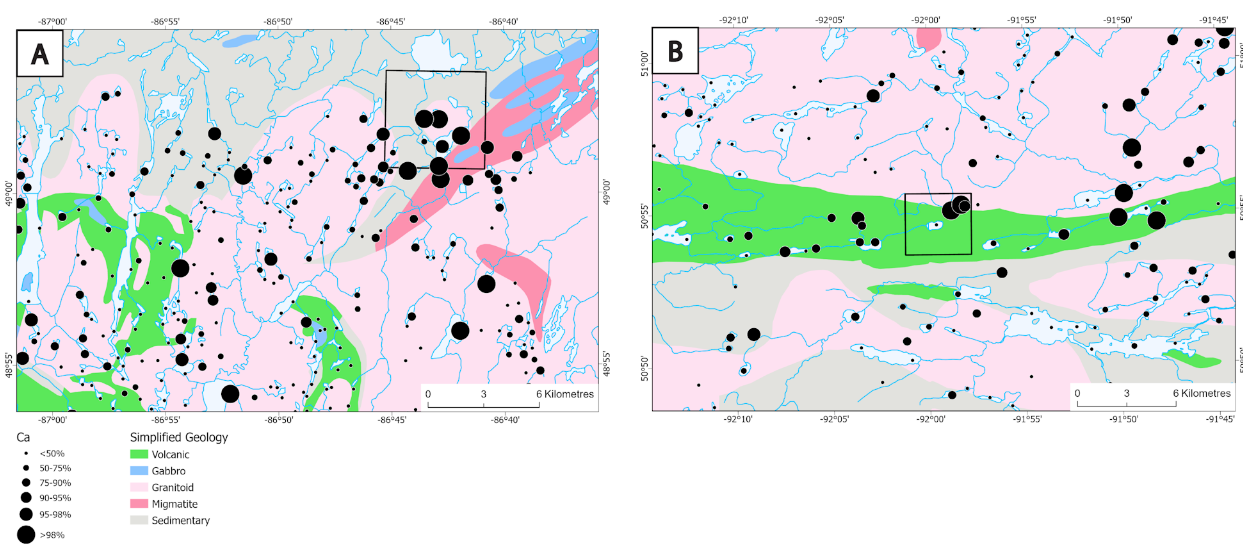

Figure 3. Maps show the distribution of calcium in lake sediment, percentiles shown as gradational dots, for **A)** the area proximal to the Prairie Lake carbonatite-alkalic complex, outlined by a black box (Dyer 1997); and **B)** the area proximal to the potential carbonatite, outlined by a black box (Ontario Geological Survey 2001). Geology *modified from* Ontario Geological Survey (2011).

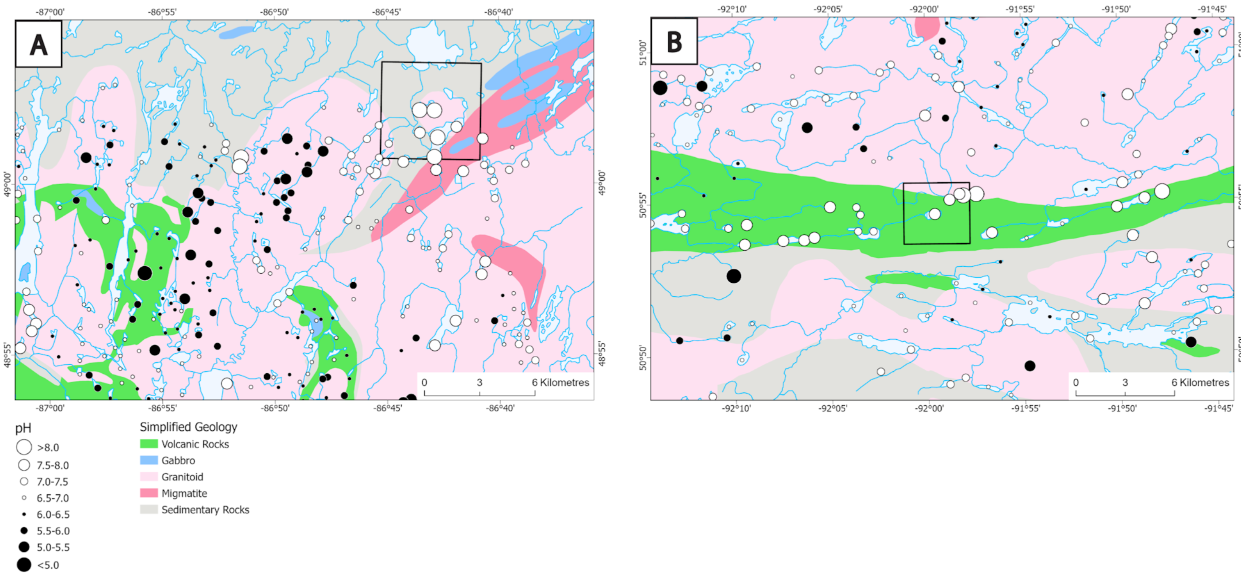

Figure 4. Lake water pH shown as gradational dots proximal to **A)** the Prairie Lake carbonatite-alkalic complex, outlined by a black box (Dyer 1997), and **B)** the potential carbonatite, outlined by a black box (Ontario Geological Survey 2001). Geology *modified from* Ontario Geological Survey (2011).

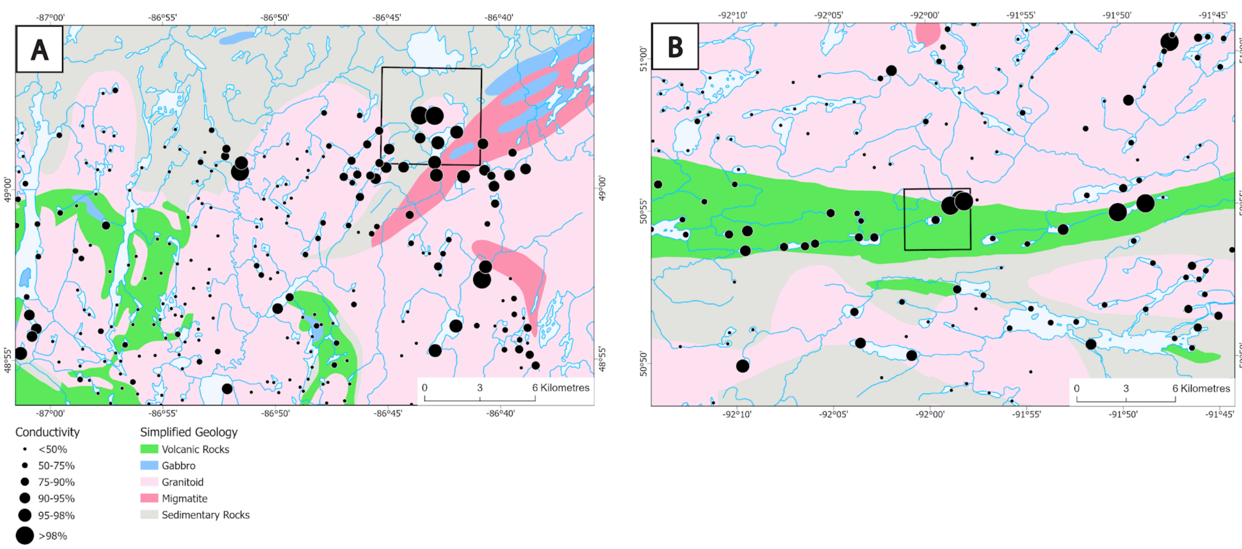

Figure 5. Maps show the distribution of lake water conductivity, percentiles shown as gradational dots, proximal to **A)** the Prairie Lake carbonatite-alkalic complex, outlined by a black box (Dyer 1997), and **B)** the potential carbonatite, outlined by a black box (Ontario Geological Survey 2001). Geology *modified from* Ontario Geological Survey (2011).

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7

HIGHLIGHTS

- **Ni–Cu–PGE potential southeast of Caribou Lake**
- **Assay data pending for samples taken during 2024 field season**
- **Area of interest overlaps with a broad area of anomalous Ni, Cr and As in lake sediment survey data**

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Nickel Potential in the Whiddon Lake and Caribou Lake Townships

Mafic and ultramafic intrusions are common in greenstone belts throughout the Superior Province and are known hosts of Ni–Cu–PGE and Cr–PGE deposits (Houle et al. 2020). There are 2 known Ni–Cu–PGE deposits in the Caribou–Marshall Lake greenstone belt, the B4-7 and VW deposits located towards the eastern end of the belt. During the summer of 2024, staff of the Ontario Geological Survey (OGS) Resident Geologists Program, Thunder Bay North District sampled mafic intrusions on the western end of the Caribou–Marshall Lake greenstone belt, to the east of Caribou Lake (Figure 1).

The area is underlain by supracrustal metasedimentary-metavolcanic rocks intruded by several phases of plutonic rocks. One of these phases includes hornblende to pyroxene gabbros of the Caribou Lake pluton and an associated swarm of dikes of the same composition (Photo 1). The Caribou Lake pluton is a medium-grained, massive to weakly foliated hornblende to pyroxene gabbro (Sage et al. 1974; Sutcliffe, Bivi and Kavanagh 1981). Just north of the mafic intrusive rocks sampled, a mafic volcanic unit with strong silicification and carbonatization was sampled as well. These strong alterations have been noted by previous mappers (Sutcliffe 1980, 1984).

Sutcliffe (1980) noted that the gabbro bodies south of Caribou Lake have potential to host copper–nickel mineralization and lake sediment sampling outlined a broad area of elevated nickel, arsenic and chromium to the immediate southeast of Caribou Lake (Ontario Geological Survey 2000). The study showed that the area is underlain by mafic and ultramafic intrusive and metavolcanic rocks; thus the elevated response may reflect the natural geochemical signature of these rocks. However, these findings have not been further investigated and there is still uncertainty whether the elevated values could be derived from host rocks rich in oxides, sulphides or silicates.

Several other geological features support the mineralogical potential of the Caribou Lake and associated plutons and intrusions. Proximity to transcrustal discontinuities is an important factor to help define prospective Ni–Cu-PGE and Cr–PGE metallotects (Houle et al. 2020). The mafic and/or ultramafic intrusions discussed here are proximal to the Caribou Lake fault and Pashkokogan Lake fault zone. The Pashkokogan is a major fault zone that separates the Wabigoon subprovince from the English River subprovince to the north. Several other mafic and ultramafic intrusions are present in the vicinity of the Caribou Lake pluton, including the Outlet Bay pluton and a mafic dike swarm, both of which are interpreted to be genetically related to the Caribou Lake pluton (Sutcliffe, Bivi and Kavanagh 1981; Sutcliffe 1984).

Churchley, S.V. 2025. Nickel potential in the Whiddon Lake and Caribou Lake townships; *in* Recommendations for Exploration 2024–2025, Ontario Geological Survey, Resident Geologist Program, p.30-32.

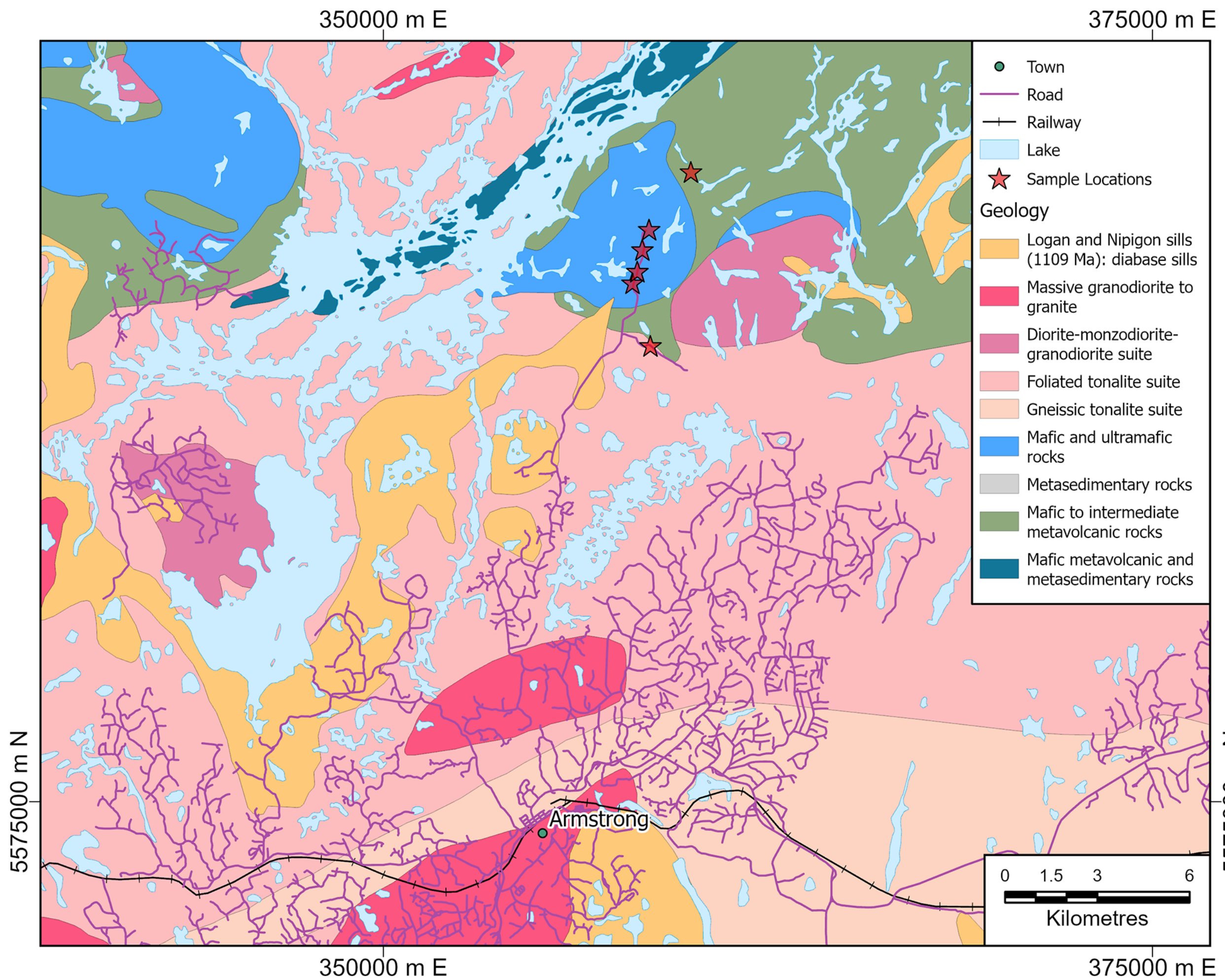

Figure 1. Map showing sample site locations from 2024 field work. Geology *from* Ontario Geological Survey (2011). Universal Transverse Mercator (UTM) co-ordinates in North American Datum 1983 (NAD83), Zone 16.

The field work conducted by the Resident Geologist Program staff in the summer of 2024 led to the collection of several mafic intrusive outcrop samples along Big Lake Road that transects the Caribou Lake pluton. Results from this sampling have been submitted to the OGS Geoscience Laboratories (Geo Labs) in Sudbury and assays are pending. The sampled rock typically had the appearance of medium-grained gabbroic rock with sulphide contents up to 1% observed in some samples. Based on the work done by Sutcliffe (1980) and the proximity to the transcrustal Pashkokogan Lake fault, the author believes in the potential discovery of Cu-Ni mineralization. Results from the 2024 sampling program will be reported in a future OGS publication.

Photo 1. Outcrop 24-BLR-005 (358418E, 5592927N, NAD83, Zone 16) of the Caribou Lake pluton crosscut by later tonalite felsic dikes.

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8

HIGHLIGHTS

- **Clusters of lake sediment Pt-Pd-Ni-Cu-Cr-Co anomalies situated along a 6 km long northwest-trending magnetic “high” anomaly**
- **Ontario Geological Survey geoscientists interpretation of magnetic geophysical and lake sediment data indicate unexposed Lac des Iles suite-type intrusion**
- **Upsala area largely underexplored**

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Platinum Group Element-Copper-Nickel Potential in the Upsala Area

Mafic intrusive rocks have potential to host platinum group element-copper-nickel (PGE-Cu-Ni) mineralization. The Lac des Iles igneous complex is host to the Lac des Iles palladium mine, currently operating 90 km north of Thunder Bay (Figure 1). The Upsala area is largely underexplored, most likely because of poor outcrop exposure; however, mafic intrusions of the Lac des Iles (LDI) suite rocks, identified as oval to circular magnetic “highs” in aeromagnetic maps, are worth further examination.

This article highlights an underexplored, northwest-trending magnetic “high” anomaly (6 by 1.2 km) situated between Gum and Herbert lakes, with coincident PGE-Cu-Ni lake sediment anomalies, potentially representing an LDI suite-type intrusion (*see* Figure 1).

The LDI suite intrusions (shown in blue, Figure 1) are predominantly mafic in composition although some bodies contain ultramafic rocks. Gabbroic to pyroxenitic and peridotitic dikes and stocks of the Lac des Iles suite occur within a broad band extending from south of Atikokan to Lac des Iles (Stone 2010a).

Most LDI suite intrusions (2699 Ma and 2686 Ma) are hosted by granitoid basement rocks in the Whistle Domain (2716 to 2729 Ma), while others have been emplaced into the Marmion (2889 to 3013 Ma) and Marmion South Margin (2830 Ma) domains. Therefore, the domain architecture may provide little control on localization of mineralization associated with posttectonic plutons (Stone and Davis 2006).

Geophysical interpretation by Stone, Fell and Metsaranta (2003) and Stone (2010b) extends the Western Heaven Lake greenstone belt further west to Gum Lake (*see* Figure 2, unit 3) compared to what is shown on the regional geology of Ontario (*see* Figure 1, Ontario Geological Survey 2011).

The Western Heaven Lake greenstone belt has an average width of 5 km and is dominated by mafic metavolcanic rocks intruded by mafic and ultramafic rocks, including gabbro, olivine gabbro, pyroxenite and peridotite (Kaye 1964; Stone 2002).

In the Upsala area, Stone, Fell and Metsaranta (2003) and Stone (2010b) mapped mafic intrusive rocks as black; typically medium to coarse grained; massive to foliated; leucogabbro, gabbro, melagabbro, rare peridotite, pyroxenite, hornblendite, lamprophyre. Sage et al. (1974), Stone, Fell and Metsaranta (2003) and Stone (2010a, 2010b) interpreted strong magnetic anomalies at Gum–Herbert lakes and Muise Lake to represent unexposed gabbro intrusions associated with the Western Heaven Lake greenstone belt (*see* Figure 2).

Campbell, D.A. 2024. Platinum group element-copper-nickel potential in the Upsala area; *in* Recommendations for Exploration 2024–2025, Ontario Geological Survey, Resident Geologist Program, p.33-39.

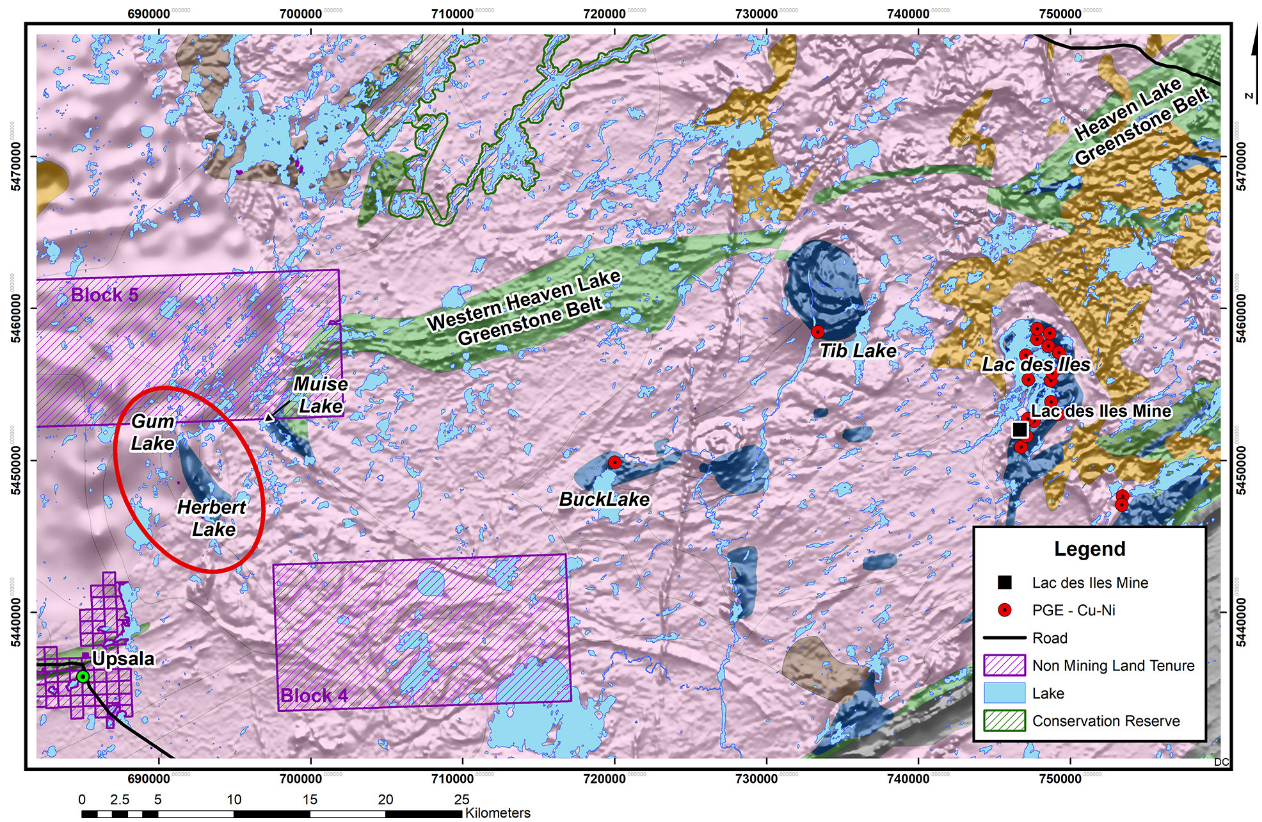

Figure 1. Regional geological map (geology *from* Ontario Geological Survey 2011) superimposed on the total magnetic shadow field (*from* Ontario Geological Survey 2003). Magnetic anomaly (high magnetic relief) situated between Gum and Herbert lakes is highlighted with a red oval outline. Archean metavolcanic rocks are shown in various shades of green; mafic to ultramafic intrusive rocks, in blue; sanukitoid rocks, in brown; granitoid rocks, in various shades of pink; and Proterozoic diabase sills and dikes, in orange. Universal Transverse Mercator (UTM) co-ordinates in North American Datum 1983 (NAD83), Zones 15 and 16. Map created by D. Campbell.

Exploration has been hindered, especially in the Gum–Herbert and Muise lakes areas, because the area is covered by glaciofluvial sand and gravel outwash deposits and eolian sand dunes in the Herbert Lake area (Mollard and Mollard 1980).

In 2002, limited exploration was carried out by Classic Gold Resources Ltd. near Muise Lake. Exploration programs consisted of a ground magnetic survey and 1 diamond-drill hole to test the magnetic anomaly (McKay 2001, McKay and Gagne 2002). The drill hole (ML-01-01) intersected a melagabbro/pyroxenite at 248.16 to 254.58 m. The melagabbro, hosted by granitoid rocks, is described as dark green, coarse grained, massive, weakly magnetic and contains no sulphides. Background results indicate slightly elevated Pt, Pd, Cr, Ni and depleted S and Cu values across the 6.42 m wide intersection. The highest values, from a 1.0 m section of the melagabbro, returned 19.5 ppb Pt, 13 ppb Pd, 101 ppm Ni and 334 ppm Cr (McKay and Gagne 2002).

The Ontario Geological Survey completed a regional lake sediment geochemical survey in the Ignace area, covering 2 sections, referred to as the Paguchi Lake and Muskeg Lake sections (Jackson 2003a, 2003b). Anomalous areas are loosely ranked by size and magnitude for both sections of the Ignace survey area. Jackson (2003a) highlights and ranks the following 3 multielement anomalous areas within the Muskeg Lake section, near Gum–Herbert lakes and Muise Lake (*see* Figures 3 to 8):

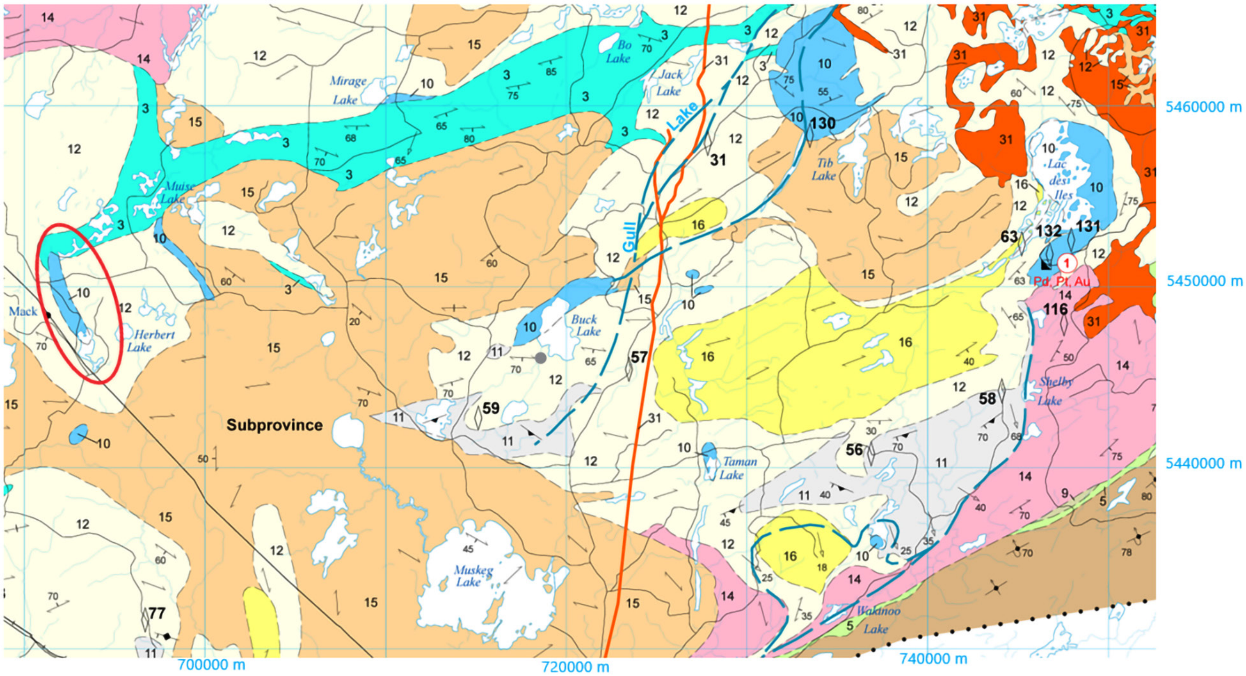

Figure 2. Geological compilation map (*modified from* Stone 2010b) with mafic intrusive rocks (unit 10) interpreted at Herbert Lake (highlighted with red oval outline). Archean metavolcanic rocks are shown in various shades of green (units 3 and 5); mafic rocks (10) in blue; sanukitoid rocks (14) in pink; granitoid rocks in various shades of grey (11), light yellow (12), light orange (15), yellow (16); and Proterozoic diabase sills and dikes in dark orangey-red (15). Universal Transverse Mercator (UTM) co-ordinates in North American Datum 1983 (NAD83), Zones 15 and 16.

1. Gum Lake (Pd, Pt, Ag, As, W, ±Cu, ±Cr, ±Ni, ±Co, ±V, ±U, ±REE, ±Sc, ±Mo)
2. Muise Lake (Pd, Pt, ±Ni, ±Cu, ±Cr, ±Co, ±As, ±W, ±V, ±U, ±Mo)
8. Herbert Lake (Ni, As, Sc, V, W, Mn, ±Pt, ±Co, ±Cr, ±Cu, ±Fe, ±Mo, ±REE, ±Th)

"±" symbol indicates elevated (90th percentile) to anomalous (95th percentile) levels
Numbers = ranking (1 to 15), REE = rare earth elements.

Jackson (2003a) reported that 2 of the sites in the Gum Lake area returned the third and fifth highest Pt values (3.7 and 2.8 ppb, respectively) of the Ignace survey area (*see* Figure 3). Most of the sites at Gum Lake contain elevated to highly anomalous values of Ag, As, W, Cu, Cr, REE, Sc and V. At Herbert Lake, 2 highly anomalous values of Ni returned 53 ppm and 44 ppm, with the former being the second highest value returned from the Ignace survey area (*see* Figure 5).

The following Figures 3 to 8 show dot plots on the total magnetic field superimposed on the total magnetic shadow field (*from* Ontario Geological Survey 2003). Magnetic anomalies are indicated by high magnetic relief, shown in pink and red. Clusters of OGS lake sediment anomalies (Jackson 2003a, 2003b) are highlighted with a black oval at Gum–Herbert lakes area. Anomalous (95th percentile) and highly anomalous (98th percentile) values represented by black dots, with analytical values, in parts per billion (ppb) or parts per million (ppm), shown in white font. Maps created by D. Campbell.

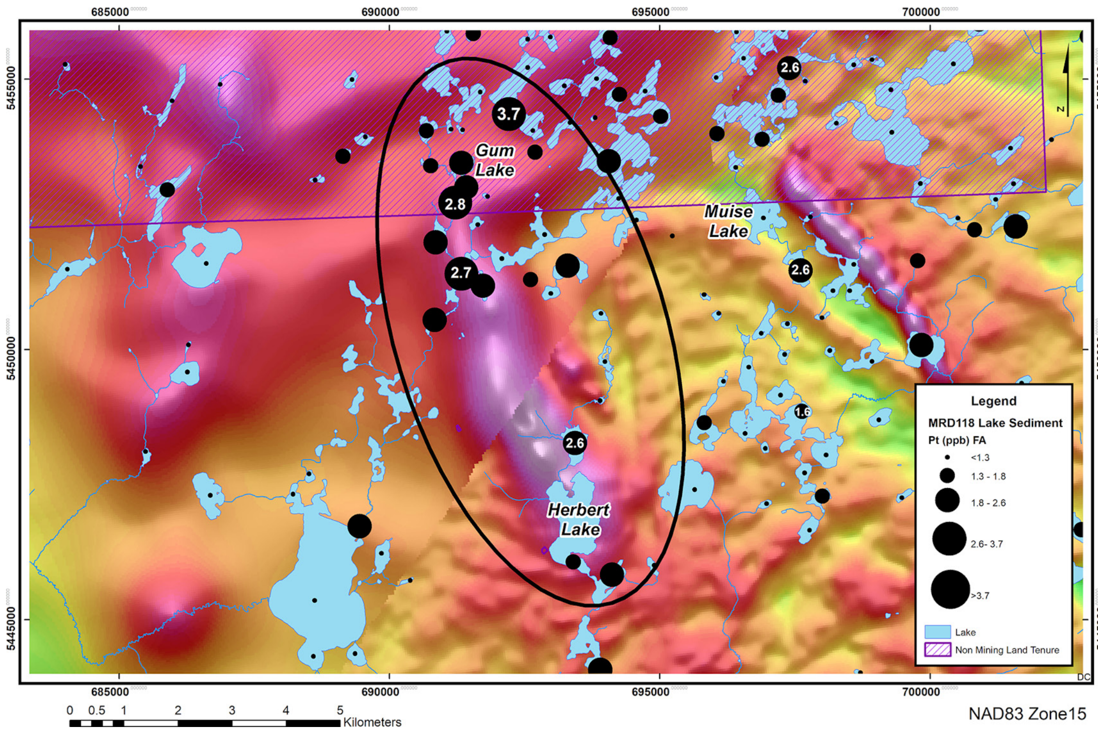

Figure 3. Platinum (Pt) lake sediment anomalies represented by black dots with fire assay values (in ppb) shown in white font (*modified from* Jackson 2003a, 2003b).

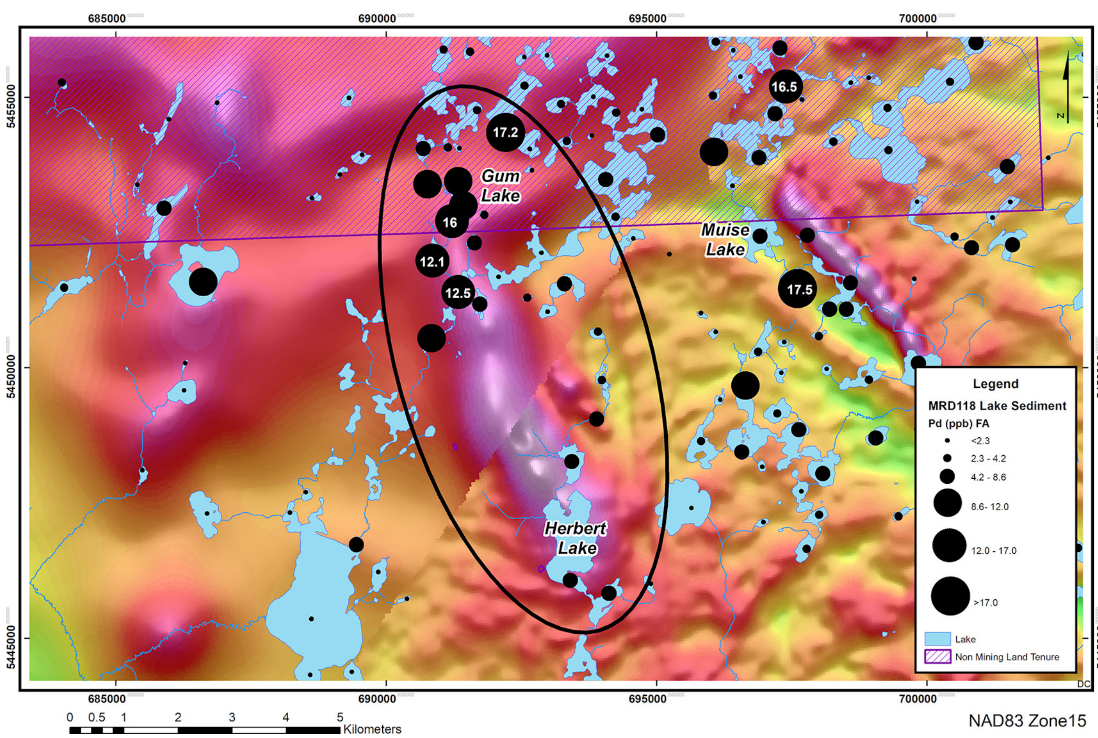

Figure 4. Palladium (Pd) lake sediment anomalies represented by black dots with fire assay values (in ppb) shown in white font (*modified from* Jackson 2003a, 2003b).

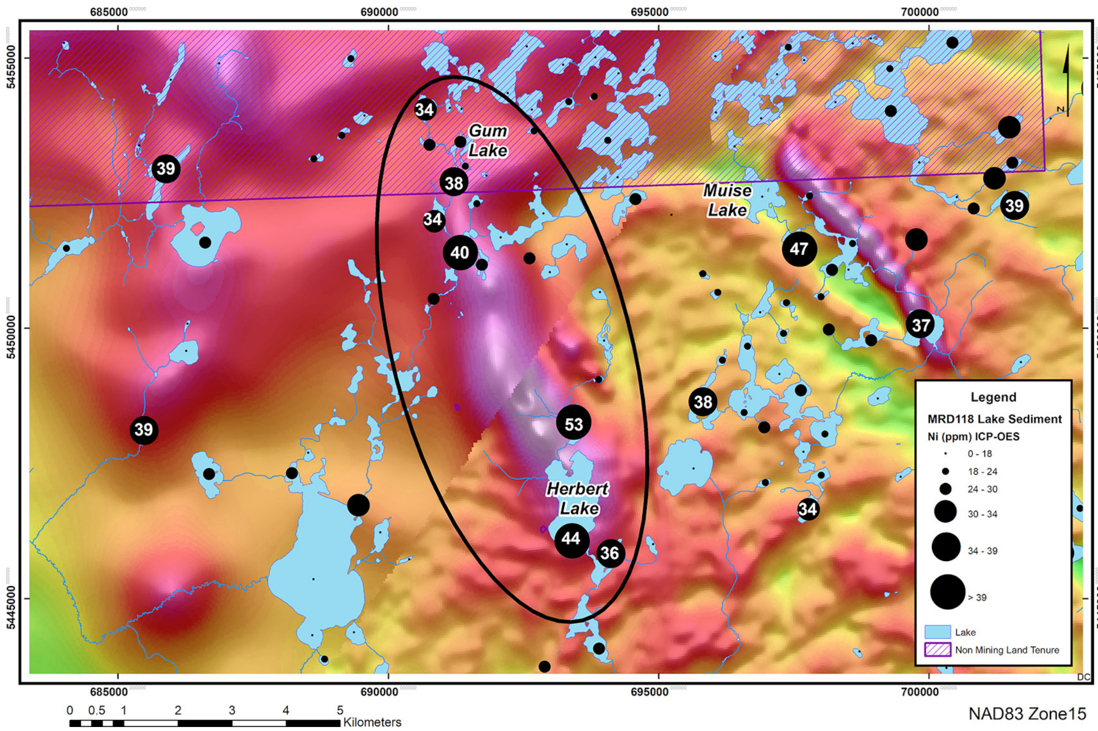

Figure 5. Nickel (Ni) lake sediment anomalies represented by black dots with results of inductively coupled plasma optical emission spectroscopy analysis (ICP–OES) (in ppm) shown in white font (*modified from* Jackson (2003a, 2003b).

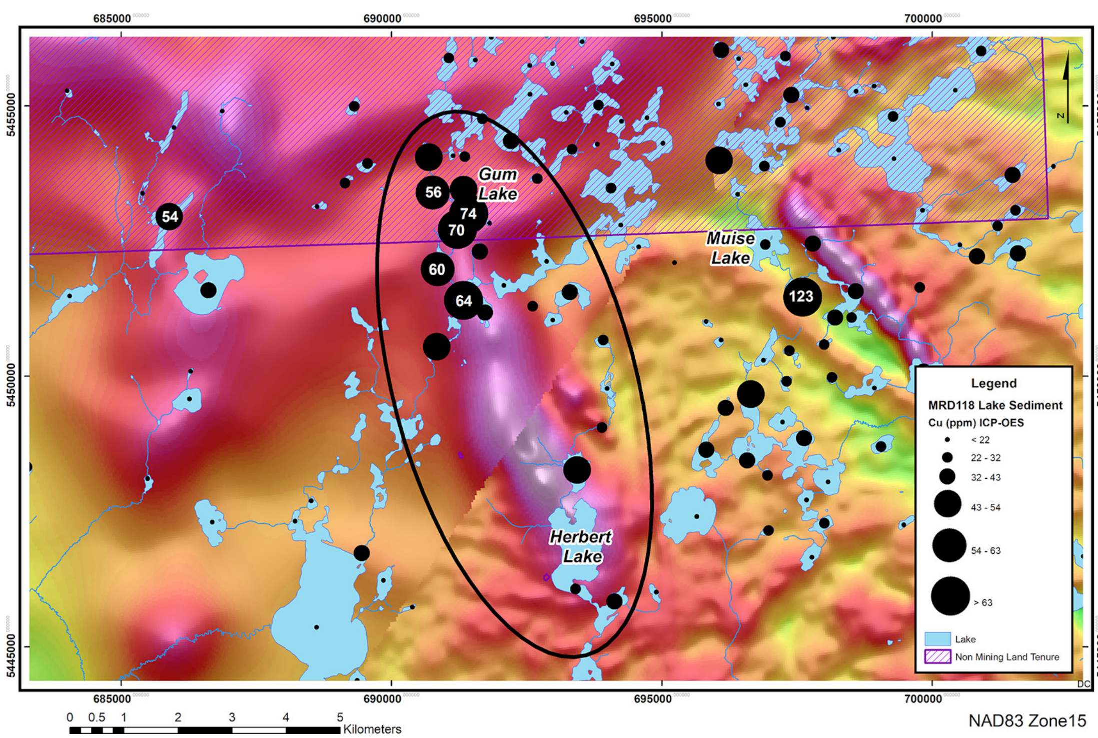

Figure 6. Copper (Cu) lake sediment anomalies represented by black dots with results of ICP–OES analysis (in ppm) shown in white font (*modified from* Jackson (2003a, 2003b).

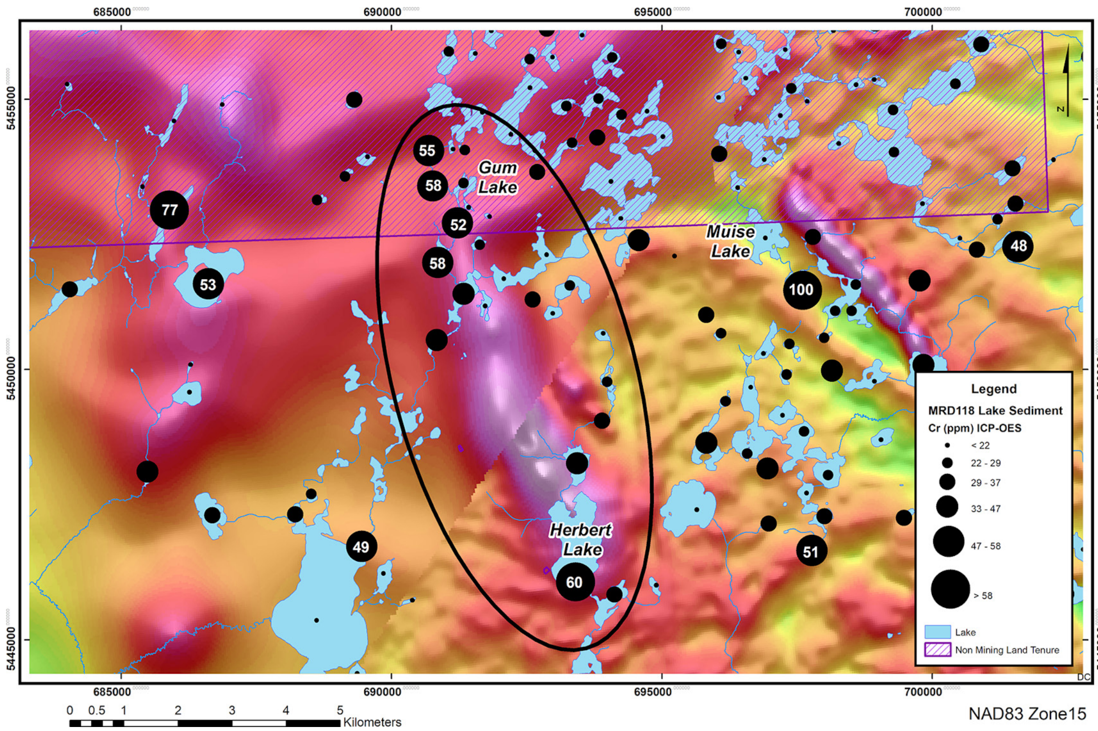

Figure 7. Chrome (Cr) lake sediment anomalies represented by black dots with results of ICP–OES analysis (in ppm) shown in white font (*modified from* Jackson (2003a, 2003b).

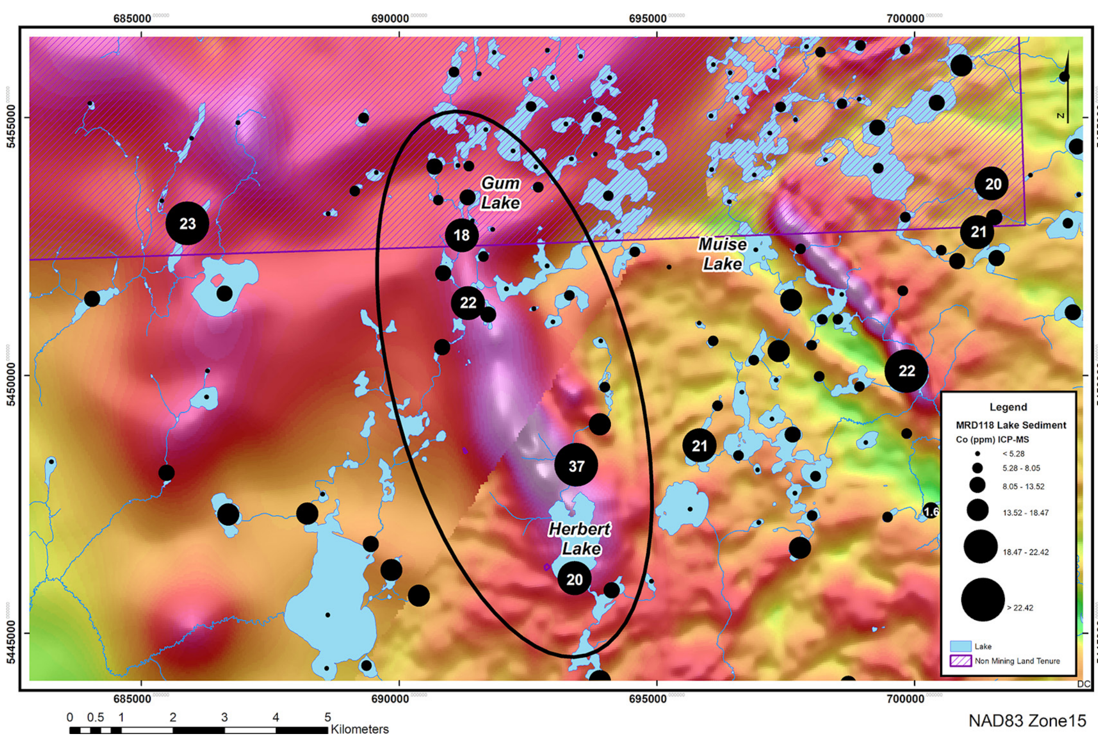

Figure 8. Cobalt (Co) lake sediment anomalies represented by black dots with results of inductively coupled plasma mass spectrometry analysis (in ppm) shown in white font (*modified from* Jackson (2003a, 2003b).

Although exploration in the Gum–Herbert lakes area is challenging because of drift cover, further exploration is recommended based on clusters of anomalous and highly anomalous multielement lake sediment metals (notably Pt-Pd-Ni-Cu-Cr-Cu) corresponding with a magnetic "high" anomaly. Both the magnetic and lake sediment data suggest mafic intrusive source rocks. Further exploration is warranted, considering there is no known exploration in the Gum–Herbert lakes area, along with increased demand and commodity prices for critical minerals, and new advances in geophysical and geochemical surveys. At the time of writing, aside from a small portion at the northern end of the magnetic anomalies, both the Gum–Herbert lakes and Muise Lake areas are open for staking.

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HIGHLIGHTS

- **North American manganese deposits are receiving renewed interest due to global supply chain risks**
- **The Animikie Basin hosts North America's highest-grade manganese deposit, but the Canadian portion of the basin has never been subject to a documented mineral exploration program focused on manganese**
- **Historical grab samples of up to 4.74% Mn have been reported from the Blende Lake area, east of Thunder Bay**

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Manganese Potential in the Gunflint Formation

Manganese Market Review

Manganese is listed as a critical mineral by both Ontario and Canada due to its importance as a cathode component in some lithium-ion batteries. Although manganese demand is dominated by steelmaking, demand from battery production is forecasted to grow rapidly, in part because of efforts to increase cathode manganese content due to its relative cost-effectiveness, energy density, and safety (International Energy Agency 2024; S&P Global Intelligence 2024). Forecasts for battery manganese demand growth vary, including 1) eightfold increase from 2020–2030 (Benchmark Minerals 2023), 2) thirteenfold increase from 2021–2031 (CPM Global *cited by* Euro Manganese Inc. 2024) and 3) thirteenfold increase from 2024–2033 (S&P Global Intelligence 2024).

The factors that make manganese "critical" are similar to those for most other critical minerals; the metal is essential for technology production and subject to significant supply chain risks. China accounts for 97% of the production of high purity manganese sulphate monohydrate (HPMSM), the primary manganese chemical used in battery production (International Energy Agency 2023). The majority of manganese mining is concentrated in just a few mines in South Africa and Australia, which can make for a highly volatile market. Temporary closure of one Australian mine due to a typhoon resulted in a near doubling of spot manganese prices between April and June 2024 (Jupiter Mines Ltd. 2024).

There has been an increase in attention on North American manganese projects in the past few years. Development projects such as Emily (Electric Metals Ltd.), Woodstock (Canadian Manganese Company Inc.), and Battery Hill (Manganese X Corp) have seen significant exploration activity for the first time in decades. On the downstream side, United States Department of Energy conditionally awarded matching US$166 million grants in September 2024 to Element 25 Ltd. and South32 Ltd. for their planned HPMSM refining facilities in Louisiana and Arizona, respectively (US Department of Energy 2024).

Cuyuna Range and Emily Deposit

The vast majority of global manganese mineral reserves are hosted in marine chemical sedimentary rocks, often but not always in association with iron formation (Cannon, Kimball and Corathers 2017). Supergene chemical weathering in tropical conditions has upgraded most of the world's largest deposits such as those in South Africa, Brazil, Ukraine, Gabon and Ghana. Manganese ore minerals typically constitute oxides (pyrolusite, cryptomelane), carbonates (rhodochrosite, kutnahorite),

Jonsson, J.R.B. 2025. Manganese potential in the Gunflint Formation; *in* Recommendations for Exploration 2024–2025, Ontario Geological Survey, Resident Geologist Program, p.40-46.

hydroxides (mangasite) and/or silicates (braunite; Cannon, Kimball and Corathers 2017).

The most relevant manganese deposit area to Ontario mineral exploration is the Cuyuna iron range in central Minnesota, approximately 160 km west of Duluth. The Cuyuna range was discovered in 1904 and is separated into 3 districts: the North range, South range and Emily district (Morey 1990). Dozens of open pit mines operated in the North range from 1911 to 1984, as did a few underground mines in the South range. Although iron was the main economic metal, manganese was a significant byproduct of some of these mines (Morey 1990). The focus of modern exploration in the Cuyuna range is the Emily deposit of the Emily district (Figure 1). It is the highest-grade manganese deposit in North America, comprising Indicated Resources of 6.2 Mt grading 19.27% Mn and Inferred Resources of 4.9 Mt grading 17.5% Mn (Forte Dynamics Inc. 2024).

The Emily deposit is hosted in the Biwabik Formation of the Animikie Group, which is correlative with the Gunflint Formation in Canada. Despite being approximately 300 km along-strike from its Ontarian continuation, the Biwabik Formation at the Emily deposit is generally similar in lithology (granular iron formation, banded carbonate-oxide iron formation, massive chert; Figure 2) and thickness (200 to 400 m) to the Gunflint Formation in Ontario (Pufahl 1996; Forte Dynamics Inc. 2024). Emily deposit mineralization is mostly hosted in 2 horizons of granular iron formation, occurring as pods, lenses, and disseminations in rocks with high primary porosity (Morey and Southwick 1993; Forte Dynamics Inc. 2024). Mineralization is interpreted to have been significantly upgraded by supergene enrichment (Forte Dynamics Inc. 2024).

Gunflint Formation – Blende Lake Area

A review of assessment reports on file with the Thunder Bay Resident Geologist's office shows that the Canadian portion of the Animikie Basin has never been subject to a documented exploration program focussed on manganese, and only a few publications report any manganese analysis results at all. The highest publicly reported manganese grades are from a prospecting program by China Metallurgical Exploration Corp. in the Blende Lake area (Keystone Associates Inc. 2011). Eleven samples were analyzed for manganese; 8 of 11 yielded values above 2% Mn with a maximum reported value of 4.74% Mn. Although this is not ore-grade, it is near the minimum threshold criteria for an Ontario Mineral Inventory occurrence (5%) and is concentrated approximately fiftyfold in comparison to the average crustal abundance of approximately 0.1% (Cannon, Kimball and Corathers 2017), warranting follow-up.

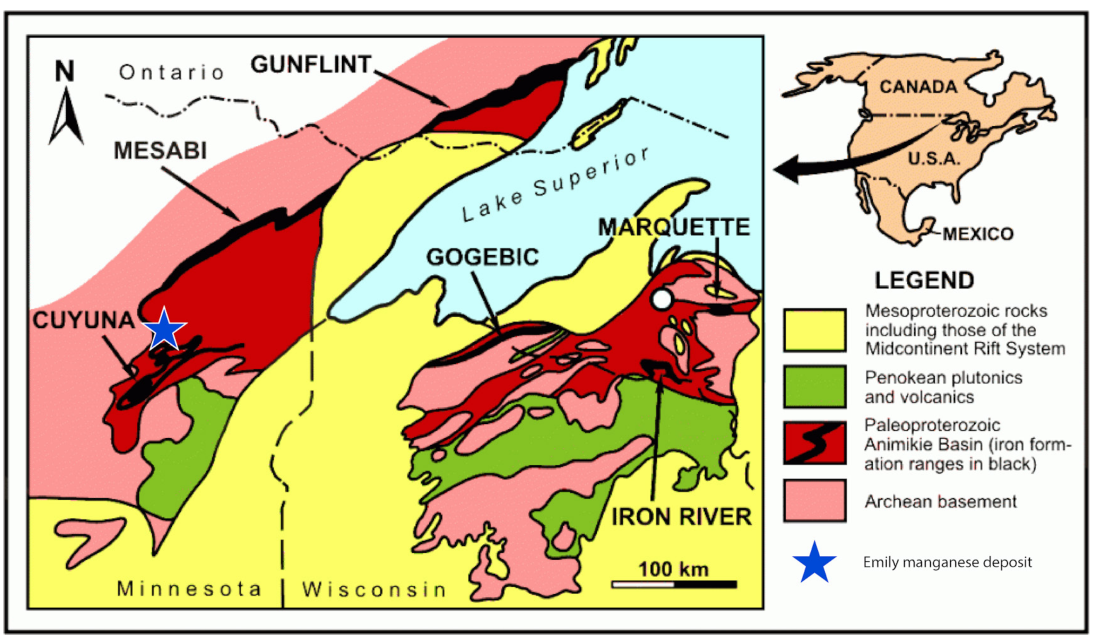

Figure 1. Location of the Emily deposit and generalized geology of the western Lake Superior region (*modified from* Pufahl, Hiatt and Kyser 2010).

Geologists from the Thunder Bay Resident Geologist's office visited the Blende Lake area on October 4 and 14, 2024, to assess historically sampled areas and other exposures of Gunflint Formation near the area explored by China Metallurgical Exploration Corp. These areas mostly comprise hematitic grainstones (Photo 1A), banded chert-carbonate (Photos 1B, 2A, 2B), and rare magnetite-rich beds. Intense supergene weathering was observed in some areas but is not widespread and most locations appear relatively unaltered beyond a few centimetre-thick modern surficial weathering profile. Data for samples taken during these field visits is pending.

Gunflint Formation – Nolalu-Gunflint Lake Area

The largest portion of iron-formation–bearing Gunflint Formation is southwest of Thunder Bay; 11 documented iron occurrences (Ontario Mineral Inventory 2024) occur in the Gunflint Formation along a 70 km stretch from Gunflint Lake in the southwest to Nolalu in the northeast. The northeastern part of this stretch (Nolalu-Whitefish Lake area) has seen the largest amount of iron exploration and several locations have reported manganese values; no samples greater than 1% Mn have been reported (Goodwin 1960; Ontario Mineral Inventory 2024).

Most of the occurrences west of Whitefish Lake have not been explored in the last 70 years and do not have reported manganese grades in published reports. Unrealized potential may exist in this very sparsely explored area. The Gunflint Lake occurrence, for example, has a reported grab sample result of 1.87% Mn (MDI000000001670, *see* Ontario Mineral Inventory 2024) and is approximately 1 km from a lake sediment sample in Magnetic Lake that yielded 0.26% Mn, which lies in the 98th percentile of all samples taken in the regional survey by Jackson (2001).

Recommendations

Many high-grade manganese deposits are small (mineral resources at the Emily deposit comprise just 11.1 Mt) and the supergene processes that upgrade manganese content also make the rocks more susceptible to weathering and erosion. Additionally, prospects or potential deposits on the Canadian side of the Gunflint Formation may be overlain by Rove Formation, Sibley Group, Midcontinent Rift-related intrusive rocks, or glacial till. Despite these challenges, the lack of focussed historical exploration programs present a potential first-mover advantage.

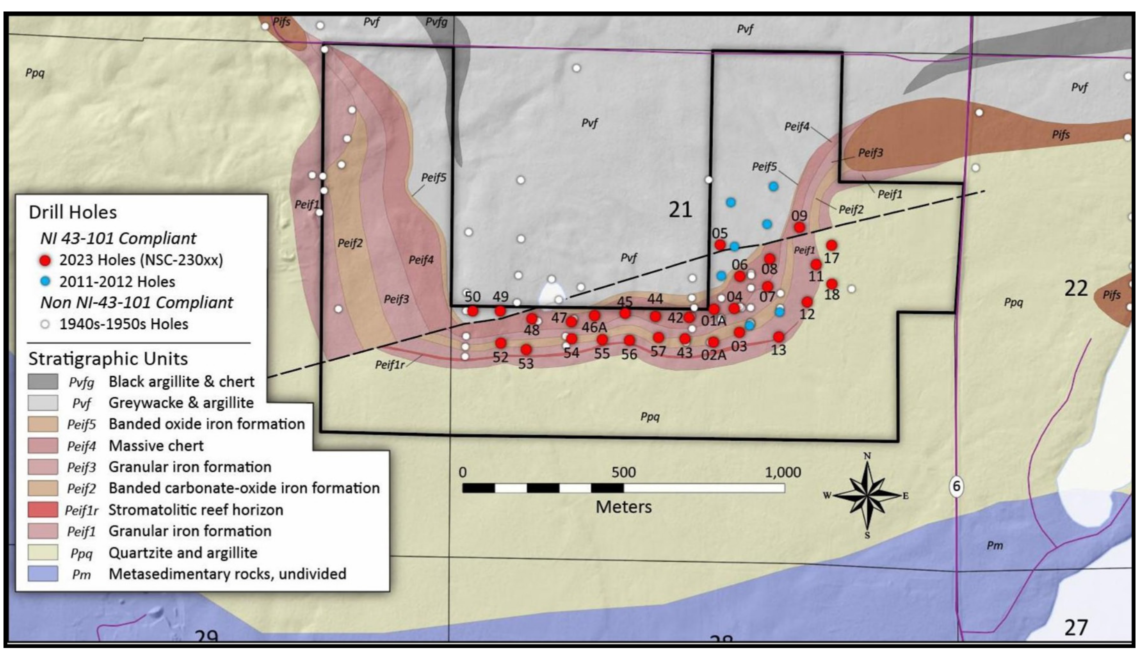

Figure 2. Geology of the Emily deposit area, with Electric Metals' property outline in black (*from* Forte Dynamics Inc. 2024).

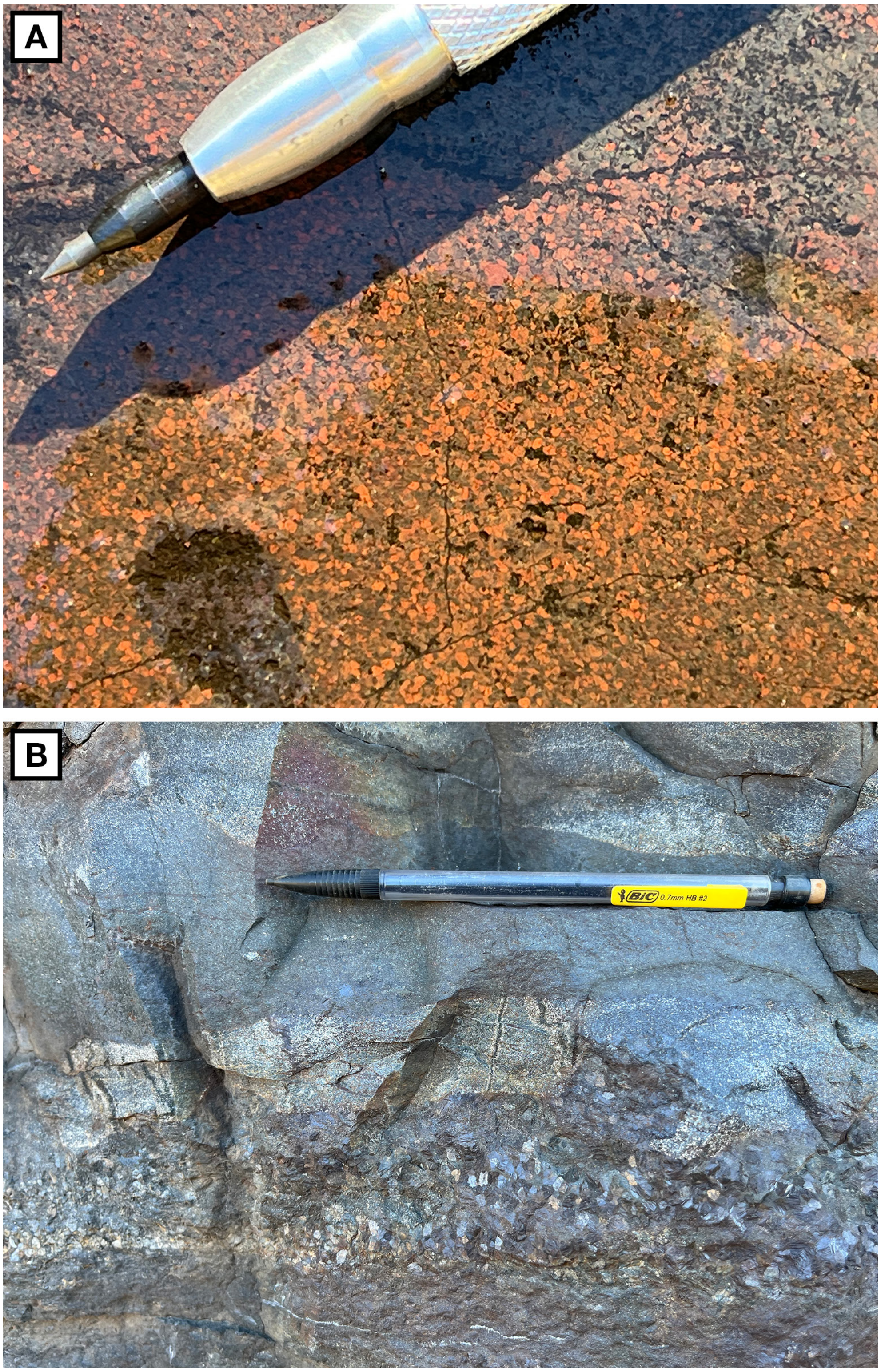

Photo 1. Gunflint Formation in the Blende Lake area. **A)** Hematitic grainstone, field of view is 4 cm (365703E 5381544N). **B)** Bed of unidentified coarse grey mineral, pencil for scale is 15 cm (367652E 5383293N). Locations are provided in Universal Transverse Mercator (UTM) co-ordinates NAD83, Zone 16. Photo credits: J. Jonsson.

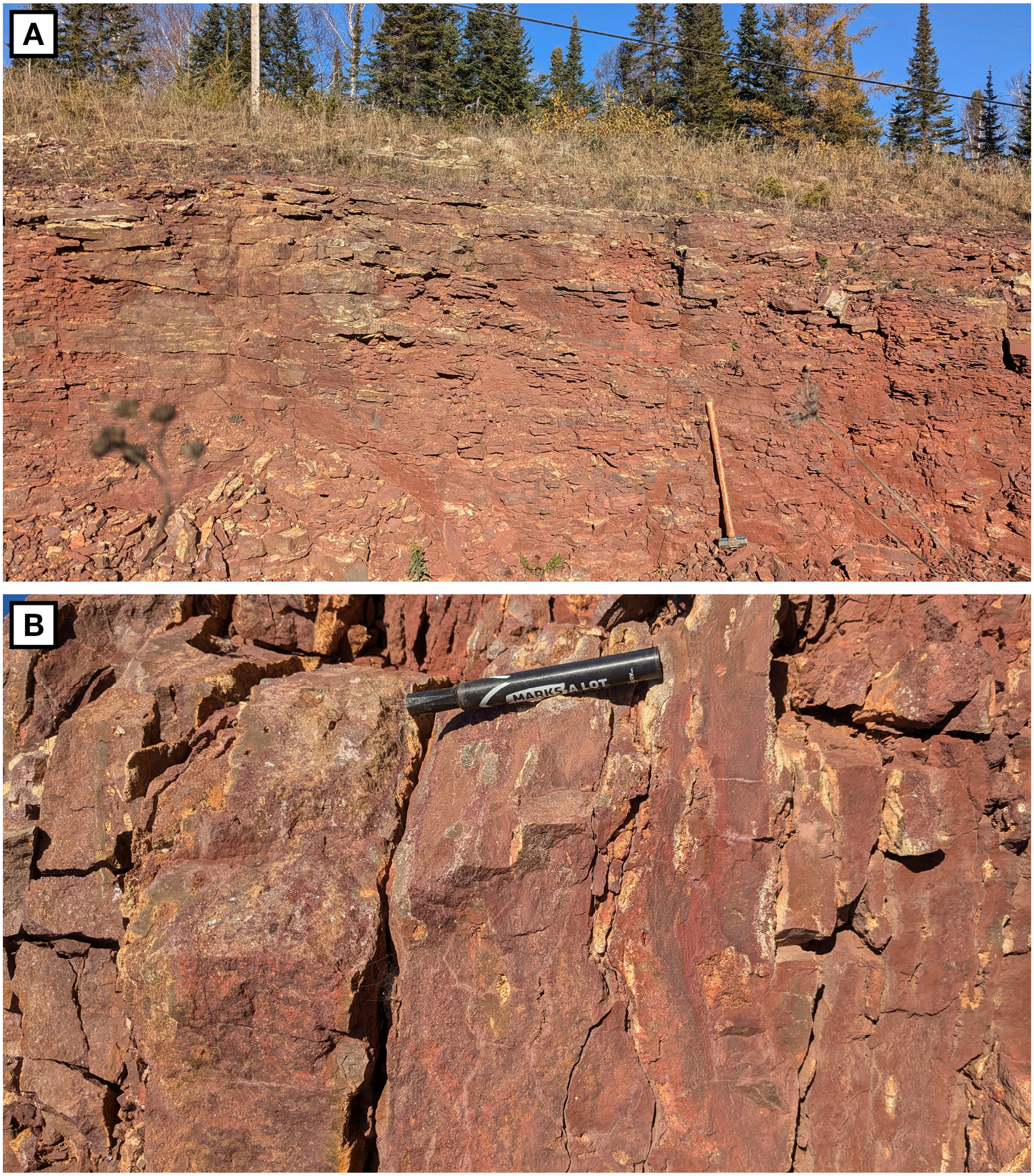

Photo 2. Gunflint Formation in the Blende Lake area. **A)** Intensely weathered bedded chert-carbonate, hammer for scale is 63 cm. **B)** Intensely weathered bedded chert-carbonate, marker for scale is 16 cm. Both photos are from a roadcut located at 369527E 5386154N, Universal Transverse Mercator (UTM) co-ordinates NAD83, Zone 16. Photo credits: J. Jonsson.

Anyone who is conducting mineral exploration for any commodity in the Animikie Basin should be aware of the characteristics of the most common manganese-bearing minerals. Rhodochrosite is typically bright pink and shows a weak effervescence to acid (similar to dolomite). Pyrolusite and manganite are dark grey/black, submetallic, and most commonly occur as massive or radiating aggregates that form discrete bands in a chemical sedimentary rock.

A key feature to look for is the presence of ancient supergene weathering, recognizable as preserved saprolite and/or pervasive limonite or hematite alteration. Several episodes of intense tropical chemical weathering of the Lake Superior region have occurred since deposition of the Gunflint Formation (Machado 1987; Medaris Jr. et al. 2003). Although this weathering is not currently recognized to have been preserved on a large scale in the Canadian part of the Gunflint Formation, special attention should be paid to stripped or diamond-drilled areas that have had little historical work or exposure of target horizons.

When diamond drilling or prospecting for any commodity in the Animikie Basin, whole rock geochemical analysis should be performed on representative samples of all variations (textures, colours, mineralogy) of iron formation, with special attention placed on strongly chemically weathered areas. On a local scale, magnetic surveys may be useful if supergene weathering has altered magnetite into hematite; interruptions in magnetic iron formation horizons should be investigated.

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HIGHLIGHTS

- **Biogeochemical sampling opens up new exploration space in the District where overburden obstructs direct observation of bedrock**
- **Black spruce trees are widespread across the District and province, providing a consistent sampling medium**
- **Previous baseline studies have shown success in correlating Au, base metal and pathfinder anomalies with historic mineral occurrences**

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Biogeochemical Sampling in the Timmins and Sault Ste. Marie Resident Geologist Districts

Introduction

Bark sampling is an underappreciated addition to the mineral exploration tool kit which has seen little application in the Timmins and Sault Ste. Marie districts. While the technique is not new and studies on the applications of plant chemistry to mineral exploration were being used in the 1980s and 1990s (e.g., Dunn 1986; Dunn, Hall and Scagel 1993; Kovalevsky 1995), recent analytical advancements, particularly the use of ICP–MS has renewed the interest in biogeochemical sampling (Dunn 2007b). Bark sampling in early exploration is an effective method that can get around common challenges faced by explorationists and prospectors in northeastern Ontario. The terrain in the Timmins and Sault Ste. Marie areas can be challenging, with extensive areas covered by water bodies and Quaternary deposits that can limit the availability of outcrops for traditional “boots on the ground” geological mapping and direct bedrock observation. While there are a variety of biogeochemical survey methods being tested in exploration, this article specifically examines the application of black spruce (*Picea mariana*) bark sampling to identify areas that may be prospective for mineralization within the Timmins and Sault Ste. Marie districts.

The basic idea behind biogeochemical survey is that metals are absorbed from soil, groundwater and locally from bedrock where roots penetrate faults, joints and cleavages. The root system of a plant may penetrate through many cubic metres of the substrate, and therefore integrate the geochemical signature of a large volume of soil, groundwater and bedrock (Dunn 2007a). Because elements can migrate upward from considerable depth in solution, by diffusion, in electrochemical cells, and possibly by seismic pumping (i.e., release of metals due to earth tremors), depth of root penetration is not critical for a biogeochemical response (Dunn 2007a).

The primary commodities explored for in the Timmins and Sault Ste. Marie districts are gold and base metals, for which the use of spruce bark sampling has been demonstrated as an effective exploration tool. In addition, the Ontario Geological Survey is currently conducting a study to assess the effectiveness of black spruce bark sampling for lithium exploration in the Kenora District (Amyotte et al. 2022; Amyotte 2023).

Recommendations

Black spruce trees are particularly suitable for this type of sampling due to their ability to uptake and store a wide array of elements in their bark

D’Angelo, V. 2025. Biogeochemical sampling in the Timmins and Sault Ste. Marie Resident Geologist districts; *in* Recommendations for Exploration 2024–2025, Ontario Geological Survey, Resident Geologist Program, p.47-50.

(Dunn 2007a). They are adaptable to various moisture levels, tolerate partial shade, and can grow in a variety of soil types (Ministry of Natural Resources 2014). The Timmins and Sault Ste. Marie districts, with its abundant black spruce population (Ministry of Natural Resources 2023) and challenging terrain (marshlands and overburden), is an ideal location to use this method. Black spruce trees are effective at storing precious metals, base metals, and potentially lithium in their bark, making them valuable indicators for the types of mineral deposits found in the region (Dunn 1986, 2007a; Amyotte et al. 2022; Amyotte 2023).

Identifying black spruce trees is straightforward, as they are characterized by their egg-shaped dark brown cones, their height of 20 to 30 metres, trunk diameter of 23 to 26 centimetres, short dark bluish-green needles, and thin scaly grey-brown bark (Ministry of Natural Resources 2014; Photo 1). For consistent and reliable results and to rule out any anomalies derived from sampling error, it is recommended that samples be collected from trees of similar height and width, and at consistent heights from the ground (Dunn 2007a).

An example of a successful sampling campaign was done by Probe Gold Inc. (*formerly* Probe Metals Inc.) on their Detour Quebec property (La Peltrie property) overlying the Abitibi greenstone belt. The sampling consisted of 1010 spruce bark samples with a spacing of 400 m covering approximately 292 km^2 (*see* Figure 1) which cover local areas of known mineralization. The known areas of mineralization were used as baseline to identify pathfinders and mineral signatures on the regional to local scale. The company was successful in identifying several new targets on the property (Beh and LaFontaine 2021) which led in part to a discovery of a copper-gold-silver-molybdenum mineralized system (Probe Gold, news release, December 6, 2022, https://probegold.com/news/probe-metals-and-midland-discover-a-large-copper-gold-silver-molybdenum-system-on-la-peltrie-option-property-detour-project/ [accessed December 13, 2024]).

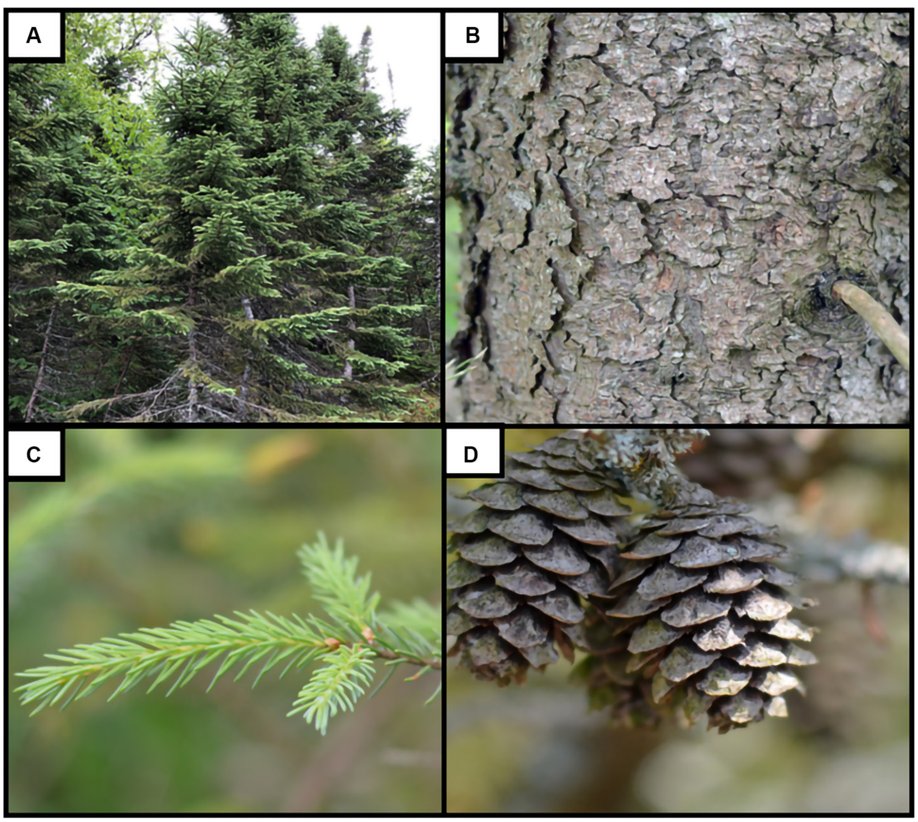

Photo 1. Key features for the identification of black spruce trees, a common species of evergreen in Ontario. **A)** Black spruce trees are generally 20 to 30 m in height. **B)** The bark of a black spruce is thin, paper like and very easy to remove, **C)** short bluish-green needles and **D)** cones are brown and egg shaped when compared to other species of evergreens in Ontario (*from* Ministry of Natural Resources 2014).

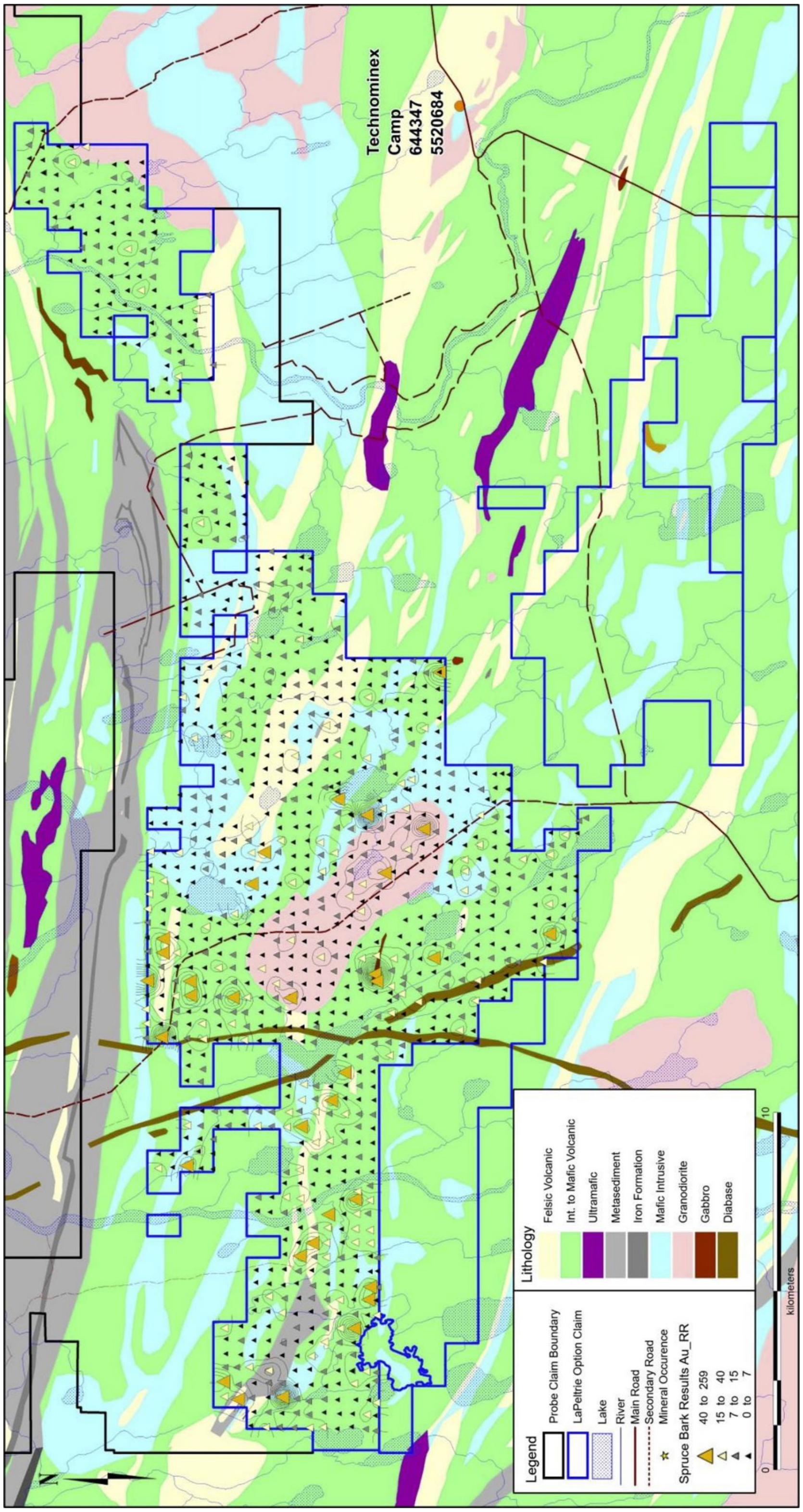

Figure 1. Results of a broad orientation survey by Probe Gold Inc (*formerly* Probe Metals Inc.) on the La Peltrie Property, Quebec. The gold concentrations in black spruce bark shows correlation with historic mineral occurrences on the property (*from* Beh and LaFontaine 2021).

Conclusions

Black spruce bark sampling is a relatively new but promising technique in the field of mineral exploration. Bark sampling allows for the collection of samples in areas with significant marshland and overburden, thanks to the resilience and widespread occurrence of black spruce. Sampling can be completed year-round, regardless of weather conditions, allowing for a compressed exploration timeline where samples can be collected in the winter and follow up studies tested the following summer. Additionally, the collection process is both cost-effective, quick and straightforward, making it an attractive option for early exploration surveys. As with any new exploration technique, it is recommended to conduct baseline surveys in areas of known mineralization as proof of concept and ensure careful data collection prior to any interpretation to achieve accurate and meaningful results.

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Gold and Copper in Felsic Intrusions of Northern and Central Kirkland Lake District

HIGHLIGHTS

- **Gold deposits in the Kirkland Lake camp are structurally controlled and are spatially associated with an alkalic complex**
- **Several gold mineral occurrences within felsic intrusions in the Kirkland Lake District**
- **Disseminated and stringer chalcopyrite and pyrite are exposed in altered syenite of the Cairo stock**

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Introduction

The gold deposits in the Kirkland Lake and Timmins districts have long been spatially associated with major deformation zones or their subsidiary faults. Most of the gold deposits in these districts are distributed along 2 distinctive but roughly parallel east–west linear trends: the Destor–Porcupine and the Larder Lake–Cadillac deformation zones (Knight 1924, Figure 1). Several researchers have studied the genesis of the gold mineralization along these deformation zones. Among others, Hattori (1993) suggested that the gold deposits in the Kirkland Lake camp are structurally controlled and are spatially associated with an alkalic complex. The deposits display early quartz-carbonate auriferous veins and evidence for a later event that introduced native gold and telluride. Ispolatov et al. (2005) have interpreted the Kirkland Lake camp as an intrusion-related gold system and compared it to epithermal systems even though Robert and Poulsen (1997) argued that the mineralizing event postdates the alkalic complex, and that gold may have been introduced late in the evolution of the Abitibi greenstone belt. Mathieu (2021) suggests that the Kirkland Lake camp may correspond to an orogenic gold system dominated by metamorphic and magmatic fluids derived from deep-seated alkaline magmas.

Moreover, in the Kirkland Lake District, 2 significant gold deposits are located within felsic intrusions: the Kirkland Lake syenitic intrusive complex located in Teck Township (Cooke and Moorhouse 1969, *see* Figure 1), and the Young–Davidson syenite in Powell Township (Sinclair 1982, *see* Figure 1). Despite this, felsic intrusions in the Kirkland Lake District have not gained any serious exploration attention. Regardless of the source of gold in the Kirkland Lake camp (structural, hydrothermal, magmatic or metamorphic), this article seeks to bring attention to key characteristics of intrusions that are associated with gold deposits and are in proximity to major deformation zones which may be relevant to the mineral explorer in the District.

Example of gold-bearing felsic to intermediate intrusions near deformation zones

Both the Kirkland Lake syenitic intrusive complex and the Young–Davidson syenite are located in proximity to the Larder Lake–Cadillac deformation zone. The Kirkland Lake syenitic intrusive complex consists of a three-phase alkalic intrusion, which includes mafic (augite) syenite, syenite, and syenite porphyry (Ispolatov et al. 2008). Whereas

Suma-Momoh J. 2025. Gold and copper in felsic intrusions of northern and central Kirkland Lake District; *in* Recommendations for Exploration 2024–2025, Ontario Geological Survey, Resident Geologist Program, p.51-55.

the Young–Davidson syenite is a multiphase intrusion that includes different textures: fine to coarse grained, porphyritic, trachytic, massive, and mafic to felsic in composition. All intrusive rocks within the Young–Davidson stock can be classified as alkali-feldspar syenite, syenite or quartz-syenite depending on the relative proportions of quartz to potassium and sodium feldspar (Martin 2012).

In addition to the above intrusions, few other gold occurrences are located within felsic intrusions, such as the Agnico Eagle Mining Limited Upper Beaver gold-copper deposit which is hosted in the Upper Beaver alkalic intrusive complex in proximity to the Victoria Creek deformation zone, a subsidiary to the Larder Lake–Cadillac deformation zone; and Kirkland Lake Discoveries' recently discovered Hurricane Intrusive Zone located between the Misema-Mist Lake fault and the Mulven-Kinabik Lake fault both of which are speculated to be the continuation of the Kirkland Lake Main Break that hosted 7 gold mines in the Kirkland Lake gold camp (*see* Figure 1). The Hurricane has returned up to 4.25 g/t gold and 0.95% copper in grab samples, (https://www.kirklandlakediscoveries.com/kl-east-side [accessed November 21, 2024]. The deposit is described as the following (https://www.agnicoeagle.com/English/exploration/exploration-projects/Upper-Beaver/default.aspx [accessed November 21, 2024]).

> Upper Beaver is a gold-copper deposit that is mainly hosted in the Upper Beaver alkalic intrusive complex and the surrounding basalts it intruded, and is associated with disseminated pyrite and chalcopyrite, and magnetite-sulphide veining associated with strong magmatic-hydrothermal alteration. The mineralization occurs as elongated tabular bodies that strike northeast, dip steeply northwest.

Outside the District, gold in felsic to intermediate intrusions have been discovered in the Marmion granitoid batholith at the Hammond Reef project affected by the Hammond Reef shear zone (owned by Agnico Eagle Mines Limited; Thunder Bay South District), and at the Côté Gold deposit near the Rideout deformation zone (currently operated by IAMGOLD Corporation; Timmins District) and its adjacent Gosselin gold zone within the Chester intrusive complex in the Swayze area of the Abitibi greenstone belt. These significant gold occurrences and findings should arouse mineral explorers to consider felsic to intermediate intrusions as possible hosts to gold ores. Côté Gold deposit geology is described as follows (https://www.cotegold.ca/en/geology [accessed November 21, 2024]).

> The Côté Gold deposit is an Archean-aged, low-grade, bulk-tonnage gold (± copper) discovery. It is described as a synvolcanic intrusion-related, stockwork to disseminated gold deposit. Deposits of this type are commonly spatially associated with and/or hosted in intrusive rocks. They include porphyry Cu–Au, syenite-associated disseminated gold, and reduced Au–Bi–Te–W intrusion-related deposits.

Selected characteristics to consider for the Kirkland Lake District

Selected significant geological characteristics for mineralized felsic to intermediate intrusions of the Kirkland Lake District are presented below and may serve as useful guides to target similar intrusions as potential gold-copper hosts in the area.

- The Kirkland Lake alkalic intrusive complex is composed of augite syenite, (felsic) syenite, feldspar porphyry, and quartz-feldspar porphyry. Feldspar porphyry and quartz-feldspar porphyry are the latest of the intrusive phases and host over two-thirds of the gold in the Kirkland Lake camp. Detailed petrography and geochemistry of the feldspar porphyry indicate that it is predominantly a quartz-monzonite (Hicks 1990).
- Disseminated and stringer chalcopyrite and pyrite in altered and sheared syenite have been associated with low-grade gold mineralization in the Kirkland Lake District as exemplified by several trenches and stripped areas north of Highway 66 in Cairo and Flavelle townships. Widely spaced diamond-drill holes and surface sampling returned 0.7 g/t gold and 0.2% copper over intervals up to 99 m from syenite in contact with sheared basalt (Berger 2006; assessment file 2.18159 *see* Larouche 1997).
- Petrography and whole rock lithogeochemistry indicate that moderate to strong sericitic, hematitic, chloritic, potassic, silicification and iron-carbonate alteration in the groundmass, fractures, and/or veinlets is an important marker to gold-copper deposits in the Kirkland Lake District and in other districts in the Abitibi greenstone belt (Berger 2006, Mathieu 2021, Dubé et al. 2024).

- The Kirkland Lake camp deposits have a distinct metal signature in gold-bearing veins (Te > Au, Mo, Pb, Ag, high Au:Ag, low As) and contains several structurally controlled deposits, demonstrating the importance of magmatic fluids in parts of the Abitibi greenstone belt (Ispolatov et al. 2005).
- The normalized multielement spider diagrams for syenite porphyry samples collected from the 144 GAP deposit of the Timmins West complex (2679±1.6 Ma; Timmins District), the Macassa Mine (2676±1.1 Ma), and the Upper Beaver deposit (2678±0.7 Ma) are similar (Figure 2), showing high ratios of light rare earth elements (LREE) relative to heavy rare earth elements (HREE), strong negative Nb, Ta, and Ti anomalies, and the absence of an Eu anomaly, which are characteristic of syn-Timiskaming alkalic/shoshonitic to subalkalic intrusions (Dubé et al. 2024).

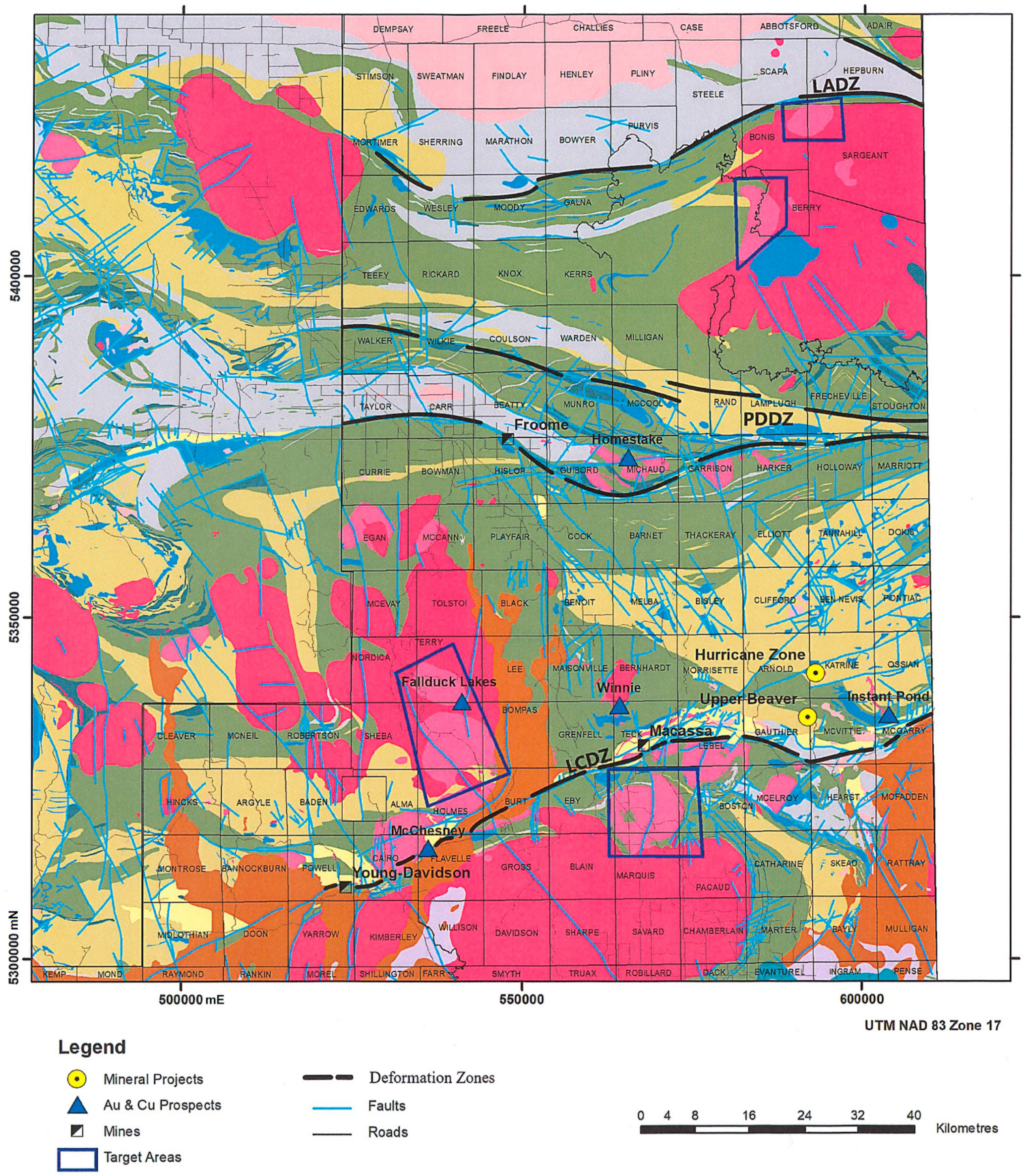

Figure 1. Geology map of central and northern Kirkland Lake District showing recommended exploration targets enclosed by dark blue polygons. Selected gold-copper projects and mineral prospects are also displayed (*from* Ontario Geological Survey 2024). LADZ = Lake Abitibi (Chicobi) deformation zone, PDDZ = Porcupine–Destor deformation zone, LCDZ = Larder Lake–Cadillac deformation zone. Modified *from* Ontario Geological Survey 2011.

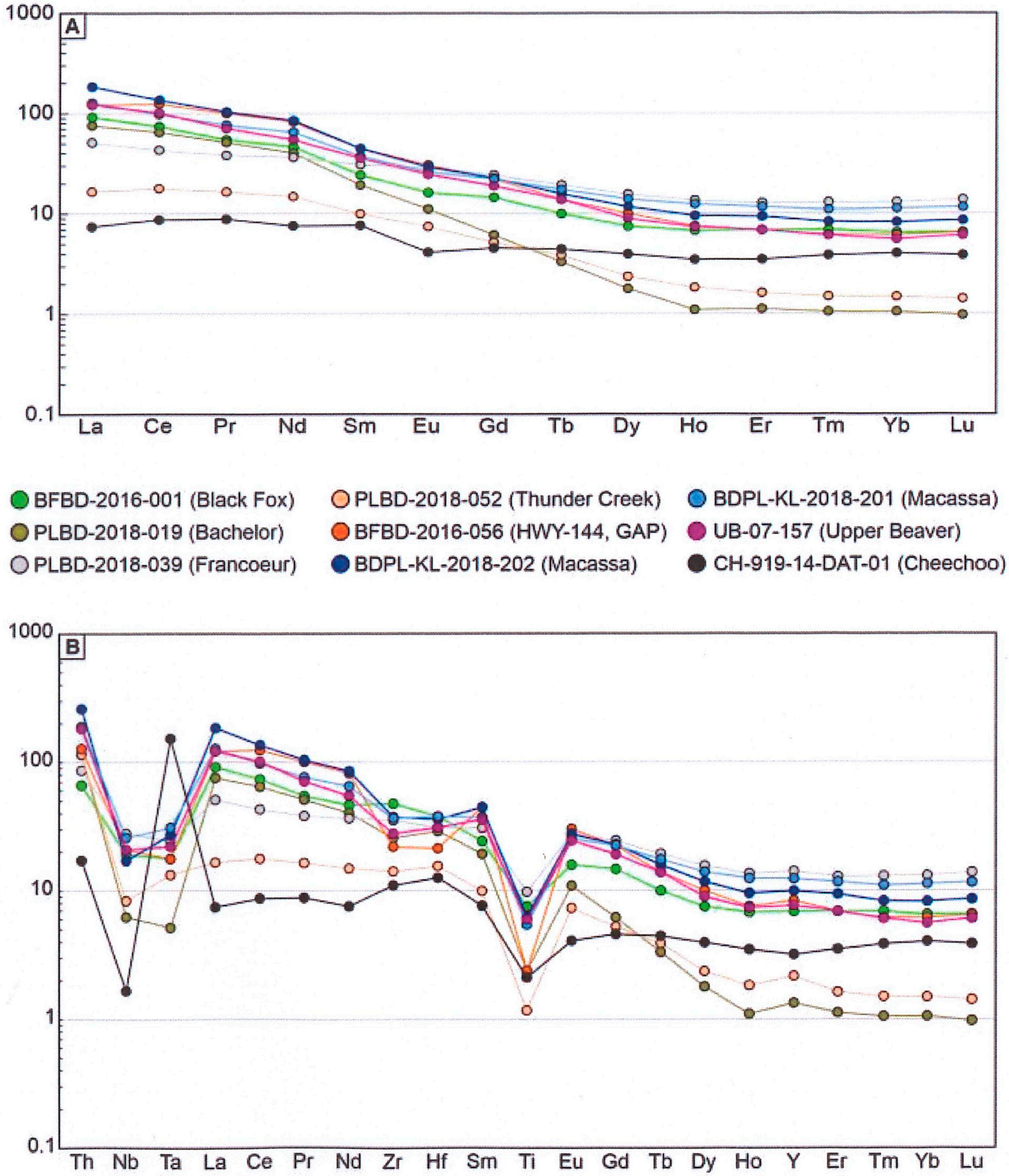

Figure 2. A) Rare earth element diagram, and **B)** multielement (high field strength elements and rare earth elements) diagram. Normalized to C1 chondrite values *from* McDonough and Sun (1995). Figure *from* Dubé et al. 2024.

Recommendation

Based on the above characteristics, 4 geographic locations available for registration have been outlined for consideration (dark blue polygons on Figure 1). These areas contain felsic intrusions in the vicinity of the deep-seated deformation zones: Larder Lake–Cadillac and the lesser explored east-trending Lake Abitibi (Chicobi) deformation zones (*see* Figure 1). The above-listed geologic characteristics and geochemical signatures of mineralized felsic intrusions may not only help guide the mineral explorer to prospective targets but also help reduce exploration costs, for example, by reducing the need for unnecessary diamond drilling.

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Regional Sodic Metasomatism, Sudbury District: The Underlying Observations

HIGHLIGHTS

- **The regional Na metasomatic zone in the Sudbury District has long been recognized as associated with gold-copper mineralization (MIAC/IOCG)**
- **Here we show the locations where Na metasomatism has been observed by Sudbury RGP District staff**
- **These observations, along with information from the OMI database, are the basis for delimiting the zone of regional Na metasomatism**

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Since the mid 1980s, the Sudbury Resident Geologist Program (RGP) has noted and studied the regional zone of sodic metasomatism in the District, and recommended exploring for gold in that zone (Meyer et al. 1986, 1989, 1990; Meyer, Campbell and Toews 1987; Meyer, Campbell and Gates 1988; Gates 1991; Cosec and Gates 1992; Meyer, Cosec and Gates 1993; Cosec, Meyer and Gates 1994; Cosec and Farrow 2011; Farrow 2012, 2017; Farrow and Bardeggia 2016; Péloquin 2018, 2023). The metasomatism has also been the subject of academic study (Schandl et al. 1992; Schandl, Gorton and Davis 1994; Schandl and Gorton 2007), particularly in the Wanapitei Lake area northeast of the City of Sudbury. However, the zone of metasomatism extends from the Bruce Mines area (Sault Ste. Marie RGP District) along the north shore of Lake Huron, to the Temagami area northeast of Wanapitei Lake, extending into the Kirkland Lake RGP District (Gates 1991; *see also* Hailstone and Farrow 2003, Figure 1). The area designated on the maps in previous Recommendations for Exploration was based on sodic metasomatism observed in the field, noted in reports, and included Ontario Mineral Inventory locations with mineralization consistent with that expected from a metasomatic iron alkali-calcic (MIAC) system (Gates 1991; Schandl and Gorton 2007, *see* Figure 1).

This summer, the Sudbury RPG office unearthed 2 original hard copy maps showing the locations where sodic metasomatism was observed by Sudbury RGP staff in the 1980s and 1990s. The regional observations (open pink circles on Figures 1 and 2) were originally plotted on maps M2361 and M2419 (Card and Lumbers 1977 and Giblin and Leahy 1979, respectively); the Wanapitei Lake area observations (open blue hexagons on Figures 1 and 2) were plotted on maps M2450 and M2451 (Dressler 1981a and 1981b, respectively). The locations shown on Figures 1 and 2 are approximations due to probable inaccuracy in field location, and the transferring of the observation locations to the digital map. It should also be noted that the observation locations are constrained by accessibility, both physical access (road and/or trail) and permission to access properties and/or claims. However, the locations, despite their inaccuracy, are important in that they helped define the extent of the regional sodic metasomatism as indicated on Figure 1.

Recommendations for Exploration

Regional sodic metasomatism is considered the "ground preparation" for the different types of mineralization found in MIAC (Corriveau, Mumin and Potter 2022, Figure 3). Details on the main alteration phase

Péloquin, A.S. 2025. Regional sodic metasomatism, Sudbury District: the underlying observations; *in* Recommendations for Exploration 2024–2025, Ontario Geological Survey, Resident Geologist Program, p.56-60.

mineralogy and metal associations for MIAC systems, including examples for each mineralization type, can be found in Table 2 of Corriveau, Montreuil, Potter et al. (2022).

In the Sudbury RGP District, particularly the Wanapitei Lake area, the regional sodic metasomatism is associated with intense low temperature Ca-Mg-Fe±K alteration (Facies 5 *in* Figure 3), which presents a wide variety of metal associations (Corriveau, Mumin and Potter 2022). However, it is the local or property-scale alteration facies, including those overprinting albitite, that will point to the type of mineralization that may be present. The facies approach of mapping alteration facies, rather than single minerals or spatial associations of minerals, facilitates the interpretation of the system shown in Figure 3.

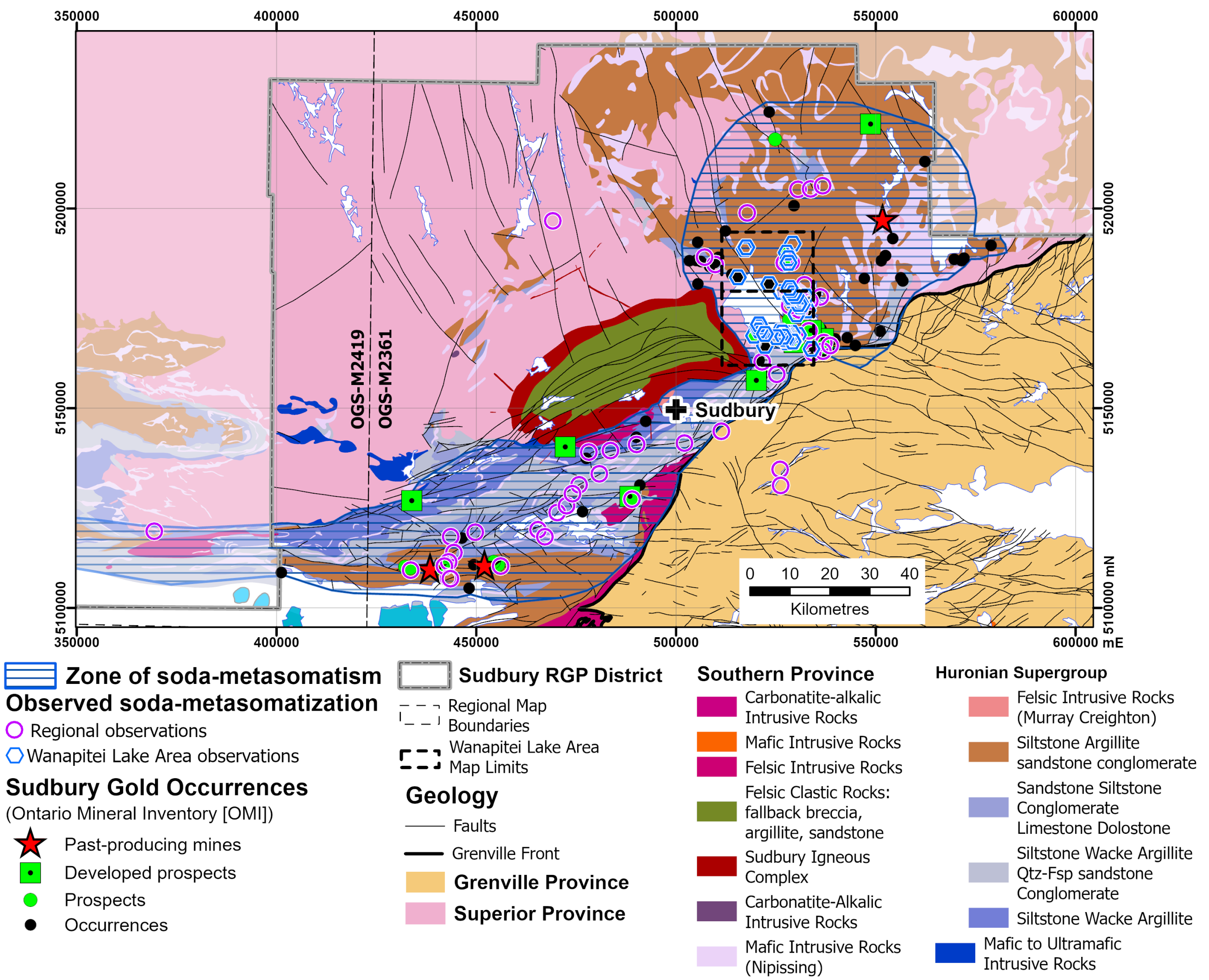

Figure 1. Regional geology map of the Sudbury RPG District, showing zone of sodic metasomatism as suggested by Gates 1991, and Hailstone and Farrow 2003, with locations where RGP staff observed metasomatism. Geology *modified from* Ontario Geological Survey (2011).

It is to be noted that iron is an important component of MIAC alteration, and although low-iron alteration types may occur, lithologies should be tested for their magnetism (metasomatic magnetite is common). However, the iron minerals can also be oxides, silicates, carbonates or sulphides, and thus may not be magnetic. The presence of structures (faults or folds), zones of higher deformation, or zones of changes in rock competency (such as contacts) should be noted, as they may have been the conduits for the fluids. Hydrothermal brecciation is commonly associated with the alteration. Geochemistry is also a useful tool to define alteration facies. A "barcode" method for the MIAC system, using molar proportions of Na-Ca-Fe-K-Mg, has been developed by Corriveau, Montreuil, Blein et al. (2022). When doing multielement analyses for this purpose, 4-acid digestion is the preferred sample preparation method, and when available, a fusion method prior to dissolution is recommended. Aqua regia digestion will not fully dissolve these rocks and should be avoided.

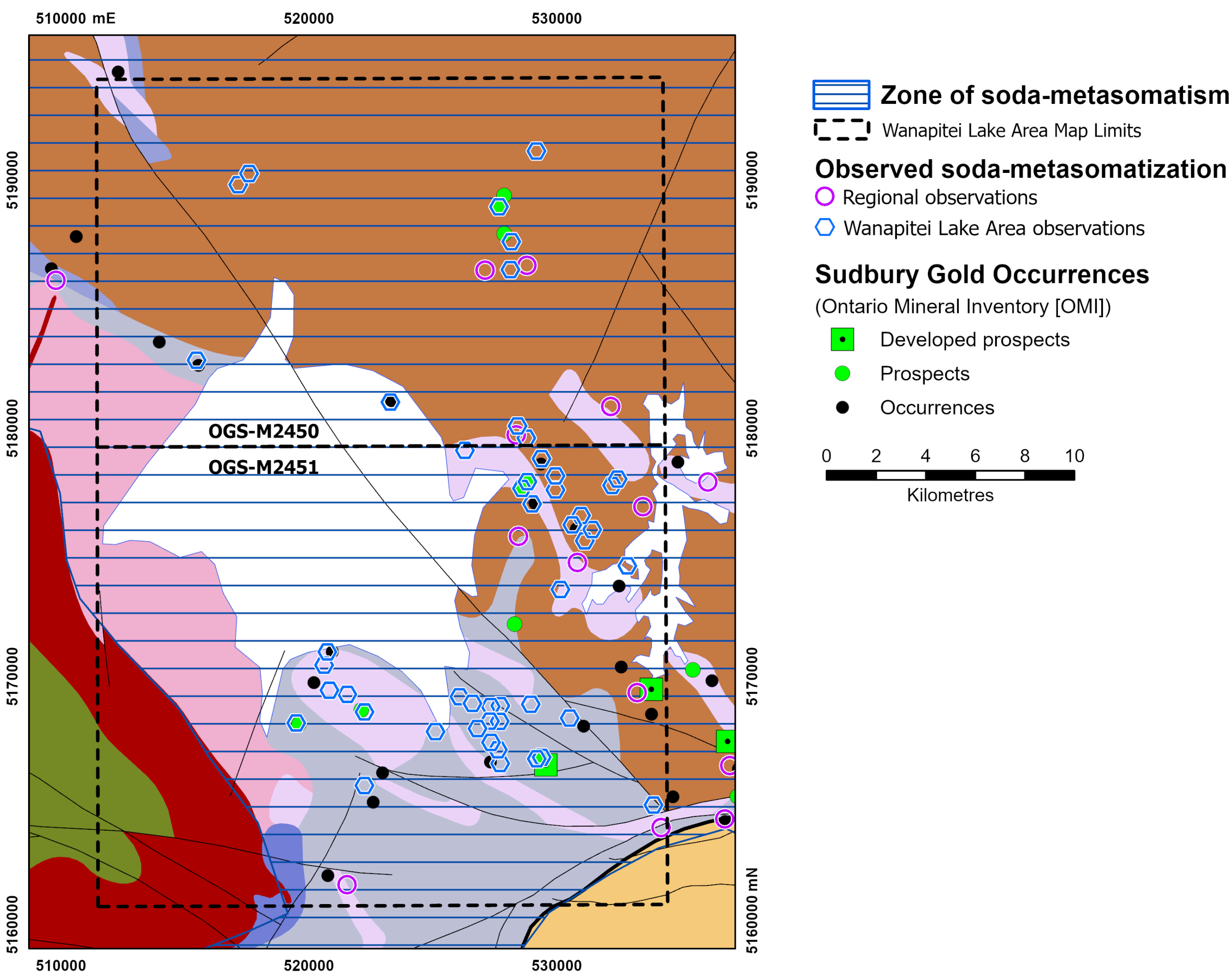

Figure 2. Local geology map of the Wanapitei Lake area (map limits are shown with dashed lines), showing locations where RGP staff observed sodic metasomatism. Geology *from* Ontario Geological Survey (2011); geology legend is same as in Figure 1.

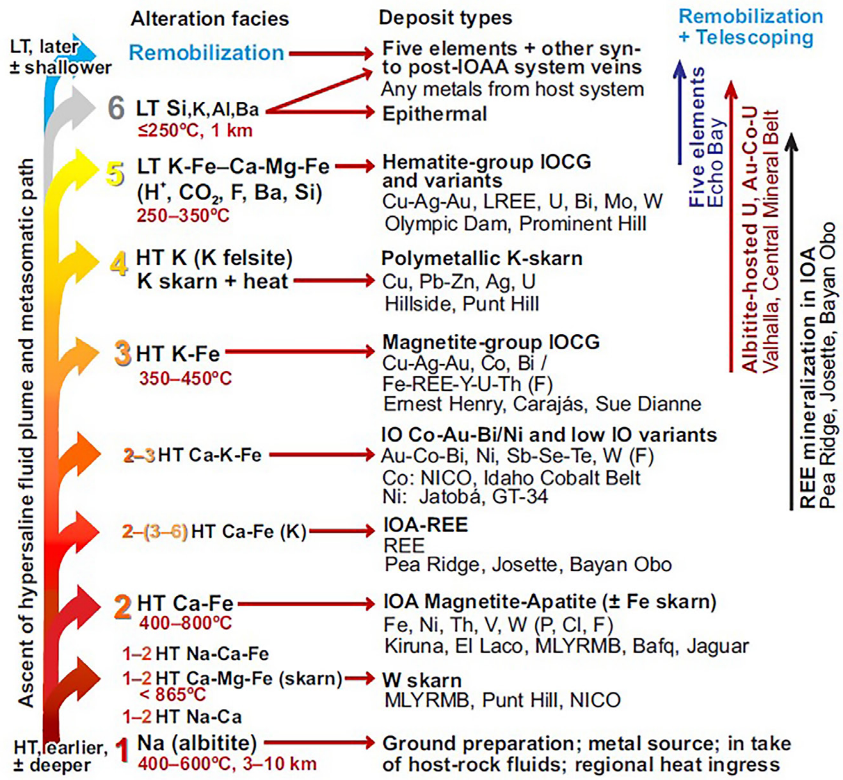

Figure 3. Metasomatic iron oxide alkali-calcic alteration (IOAA) facies (1 to 6) related to metasomatic iron alkali-calcic (MIAC) systems and their related mineral deposit types *from* Corriveau, Mumin and Potter (2022). Reproduced with permission. Abbreviations: IOA=iron oxide apatite; IO=iron oxide; LT=low temperature; HT=high temperature; MLYRMB=Middle-Lower Yangtze River Metallogenic Belt; REE=rare earth elements.

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13

HIGHLIGHTS

- **Growing interest in southeastern Ontario marbles**
- **Smaller environmental footprint using locally sourced marble**
- **Textures unique to the marbles of the Central Metasedimentary Belt**
- **Quick and easy transportation of marble from quarry to market**

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Exploration of Marble Belts in the Central Metasedimentary Belt: Decoding Textures

In the past 2 years, interest in the marbles of southeastern Ontario as dimension stone has grown resulting in increased claim registrations in the Central Metasedimentary Belt. This article will highlight the many advantages to producing and purchasing marble from southeastern Ontario.

The Central Metasedimentary Belt is composed of metasedimentary rocks including carbonate rocks (marbles; pale blue in Figure 1) and intrusive rocks (*see* Figure 1). Marbles within the Central Metasedimentary Belt have all been affected by regional tectonic metamorphism ranging from low to high grades depending on the location of the marble belt (Verschuren, van Haaften and Kingston 1985). Calcitic marbles deform plastically, whereas dolomitic marbles undergo brittle deformation. Many of the marble belts have locally undergone contact metamorphism and metasomatic alterations as well (Grant, Papertzian and Kingston 1989). The different grades of metamorphism and alteration has created many different colours and textures in southeastern Ontario marbles. It is important to note that temperatures and pressures can vary within a regional metamorphic event and can result in a variety of textures within a marble belt or single unit. Presented below are some of the variations in colour and textures that make Ontario marbles unique.

Textures of marbles within the Central Metasedimentary Belt

Marbles affected by low-grade (greenschist facies) metamorphism are fine grained and can retain primary textures such as laminar bedding (Photo 1). The laminar textures usually appear as light and dark bands millimetres to centimetres thick with variable grain sizes (Verschuren, van Haaften and Kingston 1985). The dark bands consist of impurities including graphite, phlogopite, tremolite and diopside. The level of contrast between light and dark bands depends on the amount and type of impurities (Verschuren, van Haaften and Kingston 1985).

Marbles affected by medium-grade (amphibolite facies) metamorphism are medium to coarse grained, may be lighter in colour with primary textures becoming more obscure (Photo 2). As regional metamorphism continues and metamorphic grade increases, the colour of the marble can lighten significantly, depending on impurities, often becoming much whiter (Verschuren, van Haaften and Kingston 1985; *see* Photo 2).

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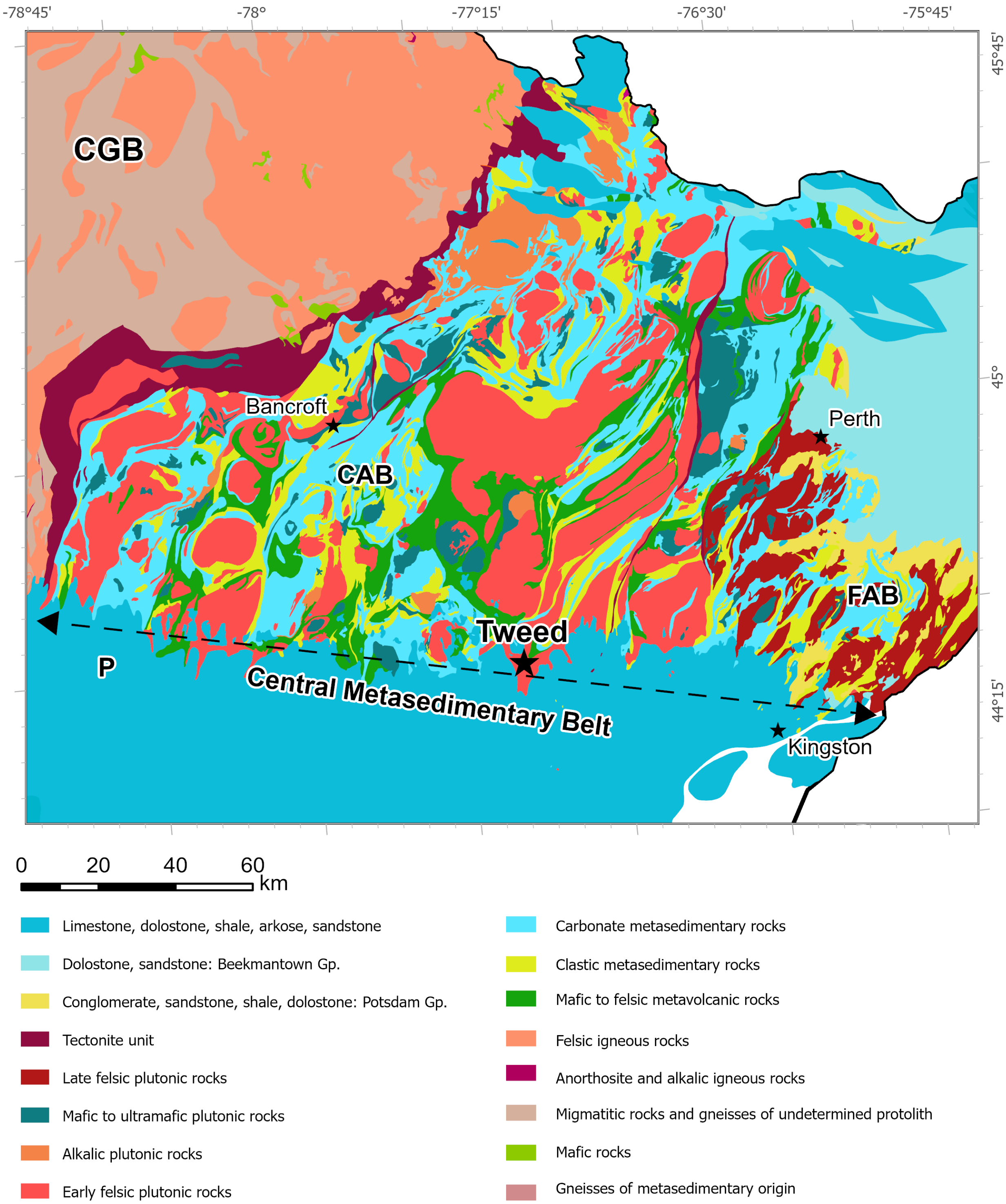

Figure 1. General geology of the Central Metasedimentary Belt depicting in pale blue the marbles units discussed in this article. Abbreviations: CGB: Central Gneissic Belt; CMB: Central Metasedimentary Belt; P: Paleozoic. Geological map *from* Ontario Geological Survey (2011).

Marbles that have undergone high-grade (granulite facies) metamorphism have recrystallized to a coarse grained or granoblastic texture (Verschuren, van Haaften and Kingston 1985; Photo 3). Any primary textures in the parent marble have been obliterated and the colour has lightened significantly, many becoming completely white. The levels of whiteness and brightness are dependent on the amount and type of impurities in the marble (Verschuren, van Haaften and Kingston 1985).

Metasomatic alteration in marble (Photo 4) occurs when magmatic fluids rich in calcium, magnesium, iron, and/or silica are introduced. These fluids interact with the marble causing chemical and mineralogical alteration of the host rock forming a skarn (https://openpress.usask.ca/physicalgeology/chapter/10-6-metamorphic-hydrothermal-processes-and-metasomatism-2/). This alteration tends to occur at and close to the contact between the marble and intrusive igneous rock.

Advantages of local sourced dimension stone

A major advantage to using locally sourced marble is a smaller environmental footprint compared to stone shipped in from overseas, particularly Europe, where the bulk of imported stone comes from (LeBaron et al. 1990). Ontario's well developed transportation network allows for quick and easy transportation of marble from quarries to building sites and retailers. Marble is low maintenance and is a "green" building material which qualifies for the Leadership in Energy and Environmental Design (LEEDS) rating system (https://www.cagbc.org/; Mancini 2021). Locally sourced marble is important to Ontario's economy. The natural stone industry contributed $850 million to Ontario's economy in 2023 and employs thousands of people across the province (Mancini et al. 2024). Another important advantage of southeastern Ontario marble is its unique aesthetics. This uniqueness has been acquired from southern Ontario's complex geological environment that is very different to the geological environment of Europe (Verschuren, van Haaften and Kingston 1985).

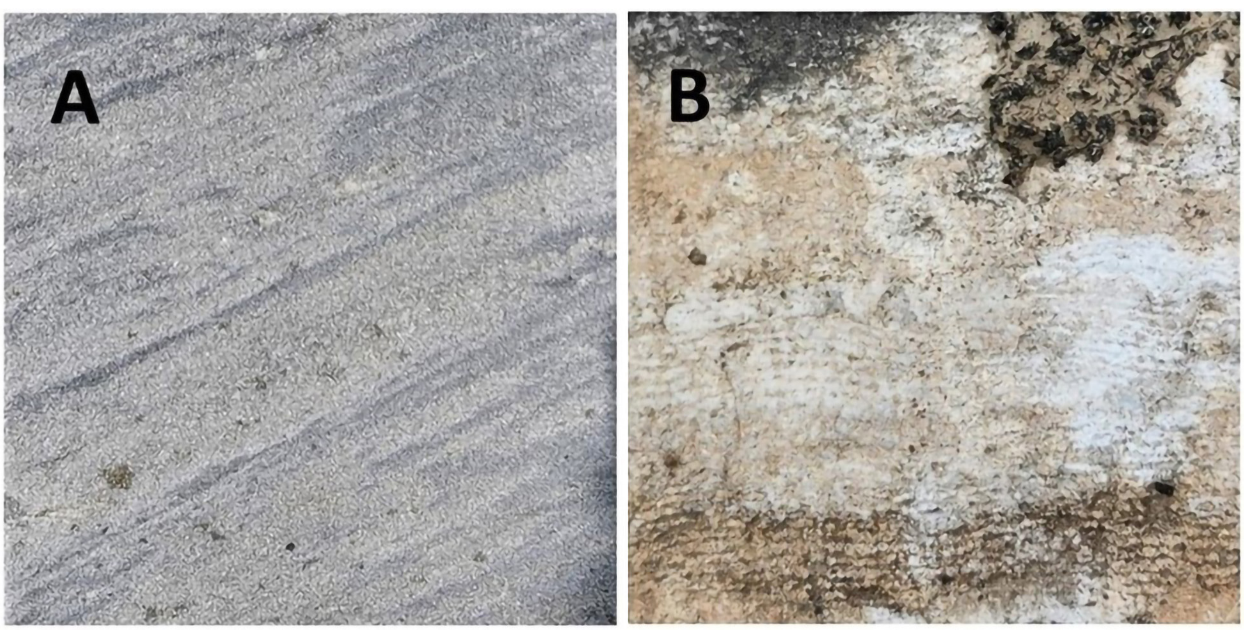

Photo 1. Examples of greenschist facies metamorphosed calcitic marble. **A)** Fine-grained banded calcitic marble with slight variations in grain sizes between bands. The grey is mainly caused by graphite with the darker bands having a higher concentration. **B)** Unpolished fine-grained dolomitic marble with well-preserved stromatolitic laminae. The marble is buff-white in colour on a fresh face and has a weathered surface in outcrop (darker discolouration). Photos by L. Mancini (2024).

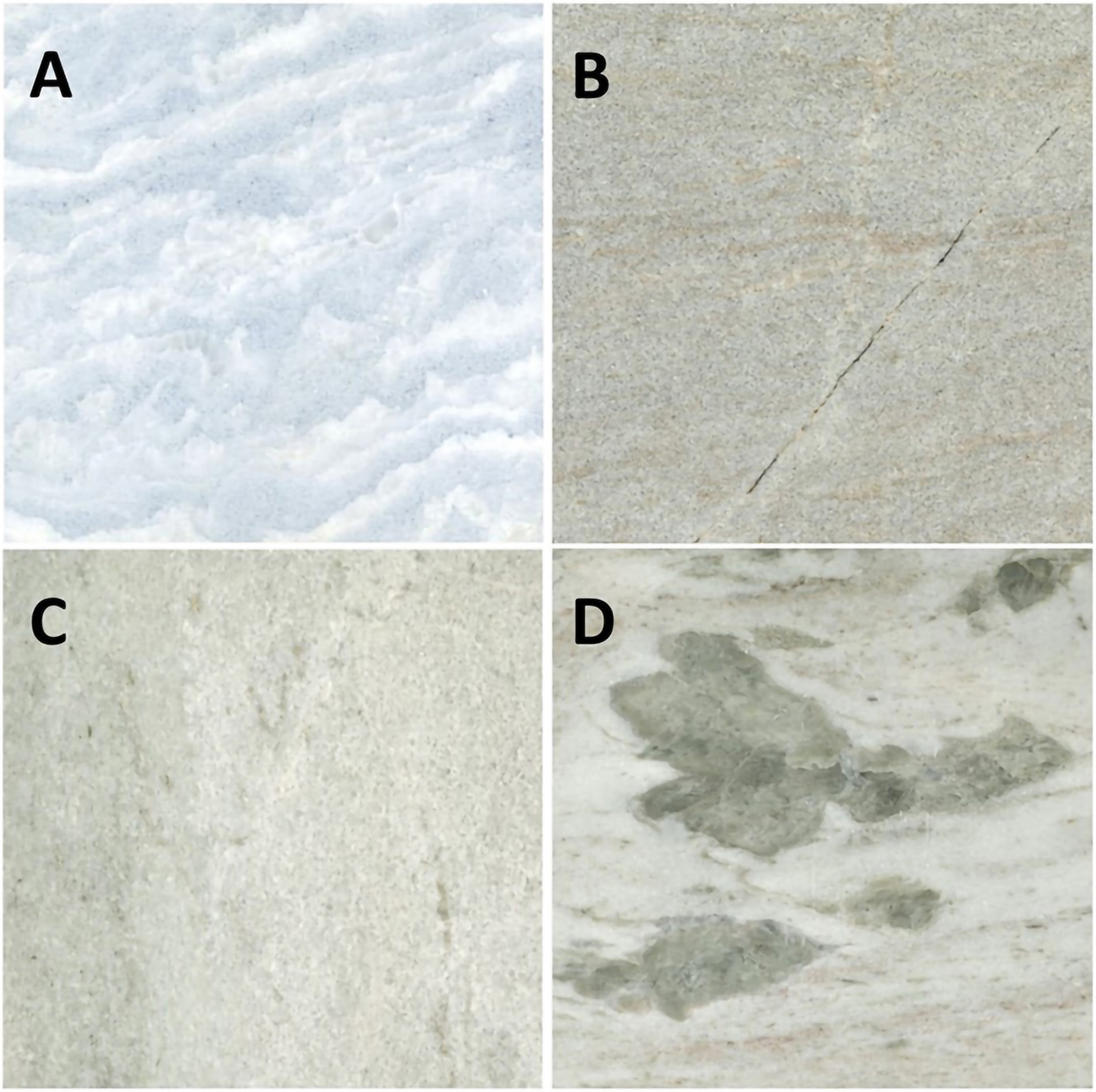

Photo 2. Examples of amphibolite facies calcitic and dolomitic marbles. **A)** Formerly laminar bedding has become crenulated in this calcitic marble. The contrast between the light and dark bands has decreased compared to the greenschist facies marbles, with the dark (blue) bands becoming significantly lighter and the lighter bands becoming pure white. Grain size has increased and granoblastic grains are visible in the white bands. **B)** Banded dolomitic marble. The grain size is increased, and the laminar bedding is less visible due to increasing metamorphic grade. **C)** Recrystallization of dolomite grains has increased individual grain sizes and has almost completely removed relict bedding. The marble is a lighter and more uniform colour. **D)** Dolomitic marble with thin calcite bands. The bands are foliated, and the calcite is coarser grained than the dolomite. Calc-silicate clots formed from remobilization of silica during metamorphism (Grant, Papertzian and Kingston 1989). The calcite bands within the dolomitic marble were possibly the source of the silica. The clots were rotated during ongoing tectonic metamorphism (Grant, Papertzian and Kingston 1989). Photos by L. Mancini (2024).

Photo 3. Granoblastic dolomite grains and the lack of relict texture result from continuous granulite facies metamorphism. The marble is a uniform white with no evidence of other colours that may have been present in the protolith. Impurities in this rock are minor resulting in a high whiteness and brightness marble. Photo by L. Mancini (2024).

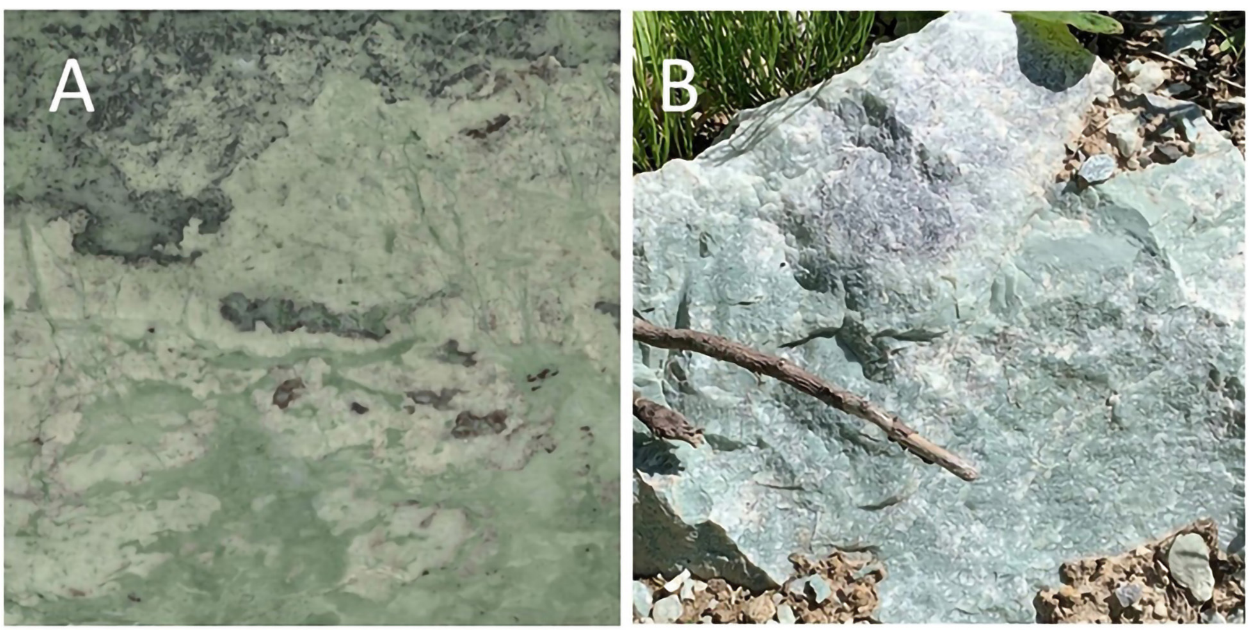

Photo 4. Examples of metasomatized calcitic marble from a quarry in Huntingdon Township located approximately 1 km south of the marble–Deloro granite contact. **A)** Polished slab of low-grade metamorphosed calcitic marble affected by later metasomatic alteration caused by intrusion of the Deloro granite. Alteration minerals include chlorite and serpentine. Photo by L. Mancini (2024). **B)** Unpolished marble. Metasomatic alteration and recrystallization have resulted in a fine-grained marble. The calcite crystals have serrated edges and are intergrown with chlorite (Vershuren, Papertzian and Kingston 1986). Samples collected by the Resident Geologist Program office in Tweed contained up to 88% tremolite. Photo by J. Swiercz (2024).

Recommendations for exploration

The criteria used by the natural stone industry (uniform appearance, hardness, deleterious minerals, and jointing) must be considered when exploring Central Metasedimentary Belt marbles for dimension stone potential. However, it is recommended that metamorphic grade should also be considered. Regional tectonic and contact metamorphism, as well as metasomatic alteration have created unique textures and colours in these marbles that are very different to those found in Europe. It is important to appreciate southeastern Ontario marbles for their uniqueness, and not compare or try to match them to European imports (Verschuren, van Haaften and Kingston 1985).

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Lidar—Digital Terrain Data for Modern Exploration

HIGHLIGHTS

- **Lidar data from across the province is becoming increasingly detailed and accurate every year**
- **Ontario Web Raster Services provide seamless access to lidar, imagery and elevation data through online services – removing the need for downloading and pre-processing large data sets**
- **Lidar-derived digital terrain models show the bare earth, seeing through vegetation and foliage**
- **Allows for easy location and determination of past bedrock workings and access trails**

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Higher Quality and More Coverage Than Ever

The Ontario Elevation Mapping Program (OEMP, https://geohub.lio.gov.on.ca/pages/ontario-elevation-mapping-program) collects airborne light detection and ranging (lidar) data across Ontario. Lidar is a remote sensing method that uses light in the form of a pulsed laser to measure ranges. The OEMP uses these data to create multiple products, including the Digital Terrain Model (DTM) which is a data set representing the bare-earth terrain – the Earth's surface, underneath vegetation and foliage. In comparison, the Digital Elevation Model (DEM) provides a generalized representation of both surface and ground features. The accuracy and detail of these data collections have progressively increased since 2000 (Figure 1), allowing for better understanding of the surface and increased utility in geoscience and mineral exploration.

As accuracy and detail increases, so too does coverage across the province (Figure 2). The program is currently focused on completing lidar coverage for the most populated areas of Ontario to support flood mapping, which means that the majority of southern Ontario has high quality, detailed lidar data available (area in pale yellow on Figure 2). Lidar coverage is available for much of the rest of the province through the Forest Resource Inventory program (in open green polygons on Figure 2; https://geohub.lio.gov.on.ca/pages/forest-resources-inventory), with slightly less detail and accuracy.

The Ontario lidar-derived DTM data set can be accessed on the Ontario GeoHub (*see* https://geohub.lio.gov.on.ca/maps/mnrf::ontario-digital-terrain-model-lidar-derived/about [accessed November 28, 2024]). The "Summary" section of the data set includes useful details such as a thorough DTM data set user guide, which would be beneficial to anyone working with the data. The data set can be processed (most easily with pre-made processing templates) to show elevation contour lines, shaded relief, slope, or hillshade. A hillshade is a grayscale image that represents a DEM in three-dimensional appearance as the human eye would interpret it with shading provided by the sun set at a specified direction (azimuth) and altitude.

Web Raster Services – Cloud Access to Huge Data Sets

Lidar data sets, like aerial imagery data sets, are massive volumes of raster data, that users typically needed to order, download, store, pre-process, or locally distribute to use functionally. Ontario Web Raster Services are a series of online services that provide access to seamless

Dorado-Troughton, M. 2025. Lidar—digital terrain data for modern exploration; *in* Recommendations for Exploration 2024–2025, Ontario Geological Survey, Resident Geologist Program, p.67-70.

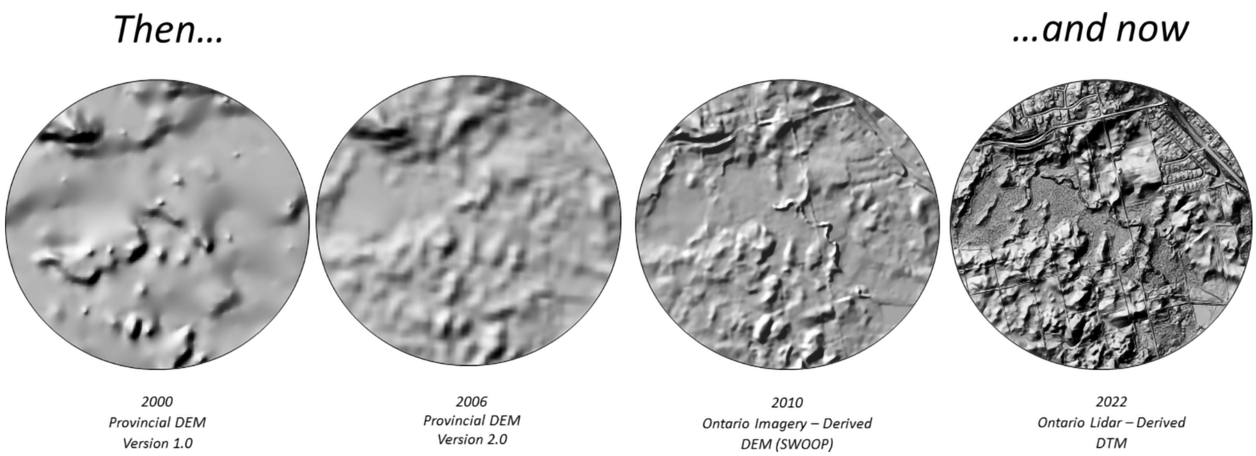

Figure 1. Increasing detail in lidar-derived elevation data, 2000 to 2022 (*from* Ontario GeoHub https://geohub.lio.gov.on.ca/pages/ontario-elevation-mapping-program [accessed November 28, 2024]). Abbreviations: DEM, Digital Elevation Model; DTM, Digital Terrain Model; SWOOP, Southwestern Ontario Orthophotography Project.

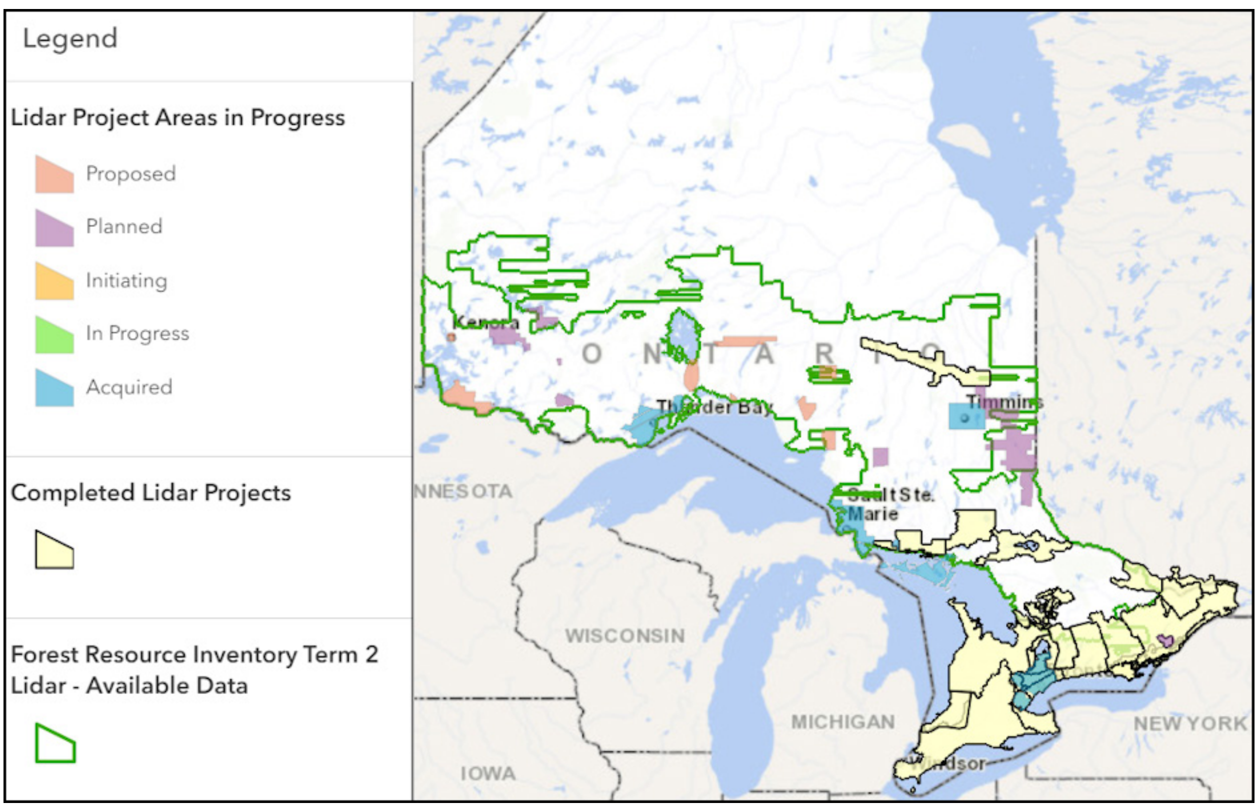

Figure 2. Map showing lidar coverage in Ontario. Note the modern, detailed and high-quality data sets available in the pale yellow areas for most of southern Ontario (*from* Ontario GeoHub, https://geohub.lio.gov.on.ca/pages/ontario-elevation-mapping-program [accessed November 28, 2024]).

imagery, elevation, landcover and lidar raster data for visualization, geoprocessing and analysis. These services allow users to work with massive, high-quality data sets on demand.

Web Raster Services use ArcGIS Image Server technology and are best accessed through a Representational State Transfer (REST) endpoint but can also be accessed through Open Geospatial Consortium compliant Web Coverage Service (WCS) URLs and thus are usable with an open-source geographic information system such as QGIS.

A detailed user guide for this service can also be found in the "Summary" section of the Ontario DTM data set (*see* https://geohub.lio.gov.on.ca/maps/mnrf::ontario-digital-terrain-model-lidar-derived/about [accessed November 28, 2024]). The user guide provides thorough tutorials, information on online service functionality and links to additional learning resources. It also provides addition information on processing and processing templates for imagery and lidar data sets.

Lidar as an Exploration Tool

Ontario's publicly available and free lidar-derived DTM data sets are a low-cost tool that should be incorporated into mineral exploration programs, land-use geology, and bedrock mapping wherever possible. The highly detailed bare-earth terrain models can have a significant impact on reconnaissance surveys and throughout the exploration process. Hillshade processing of the DTM makes roads, trails and other methods of access readily apparent. Disturbance of the bedrock surface such as historical workings like pits, trenches and shafts, even if overgrown by vegetation, are easily distinguished.

To illustrate this, an historic gold mine from southern Ontario is used as an example. Figure 3 shows the layout of the Craig gold property (MDI31C12NE00014, Ontario Geological Survey 2024) from a 1985 sketch map of the property (Figure 3A) and a lidar-derived DTM with hillshade of the same property (Figure 3B). The illustrated

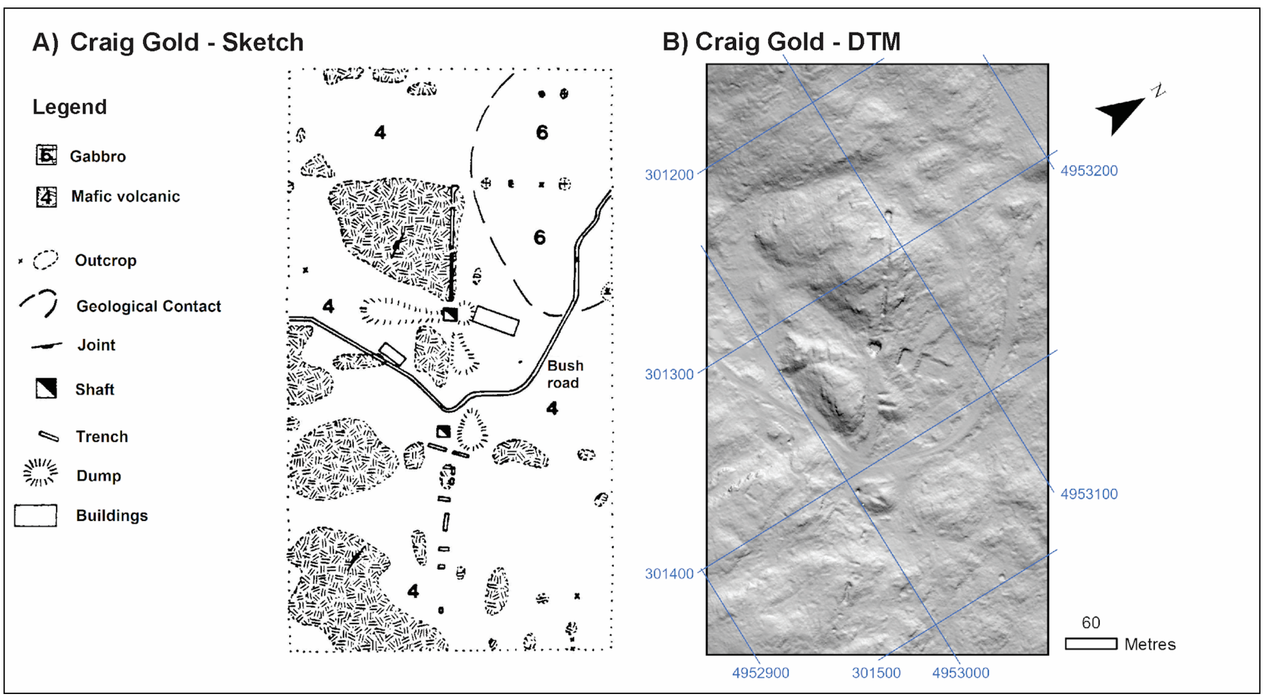

Figure 3. A) Geologic sketch map of the past-producing Craig gold property (MDI31C12NE00014, Ontario Geological Survey 2024; *modified from* Malczak, Carter and Springer 1985). **B)** Image of lidar-derived digital terrain model with hillshade from UTM zone 18, NAD83. The image is based on ArcGIS Pro's Traditional Hillshade processing template, which uses single illumination, a sun azimuth of 315° and a sun altitude of 45° above the horizon. The figure has been rotated 60° to match the orientation of the sketch map.

features of the property are visible and distinct within the lidar-based figure. The road, foundations, shafts, trenches and dumps are apparent and could be easily georeferenced within a geographic information system. Additional workings, disruptions to the dump piles, and bedrock outcrop are also visible.

Ontario's mining and mineral exploration history largely began in the Southern Ontario District, with an abundance of mineral exploration being conducted before the Mining Act and modern record-keeping. Historical workings are common throughout the District but are usually poorly located or too overgrown to find on foot. While lidar data sets are available for much of the province, the highly detailed and accurate data available in the District is an invaluable resource for locating these past workings with incredible accuracy.

References

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Ontario Geological Survey 2024. Ontario Mineral Inventory; Ontario Geological Survey, Ontario Mineral Inventory, online database, October 2024 update. www.hub.geologyontario.mines.gov.on.ca

Notes

Notes

Back inside cover photos, from top to bottom:

Amy Brush (Summer Student, Resident Geologist Program, Thunder Bay North District) poses next to a large spodumene crystal at Green Technology Metals' Ltd. Seymour Lake Property, northwest of Armstrong. Credit: Sophie Churchley, Resident Geologist Program.

Deformed metasedimentary rock in drill core stored at the RGP's Thunder Bay outdoor core storage facility. Credit: Mateo Dorado-Troughton, Resident Geologist Program.

International Lithium completed a drill program in July 2024 on their Firesteel Copper project, located approximately 10 km west of Upsala. The Firesteel Copper property was acquired by International Lithium from local prospector Byron Holbik. From left to right: Victor Lum, Jeremy Beales, Anthony Kovacs, Byron Holbik, and Daniel Gianotti.

Vittoria D'Angelo (Acting Regional Resident Geologist, Resident Geologist Program, Timmins District) examines the Gowganda Formation during a field trip of the Huronian Supergroup in the Elliot Lake area. Credit: Véronique Gagnon-Coderre, Resident Geologist Program.

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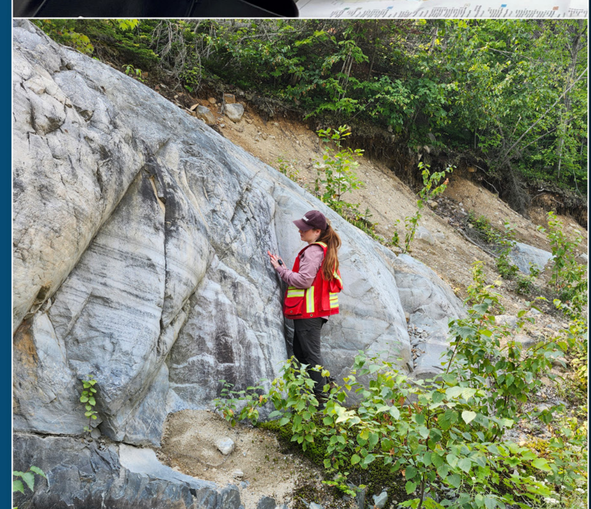

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