Recommendations for Exploration 2020–2021

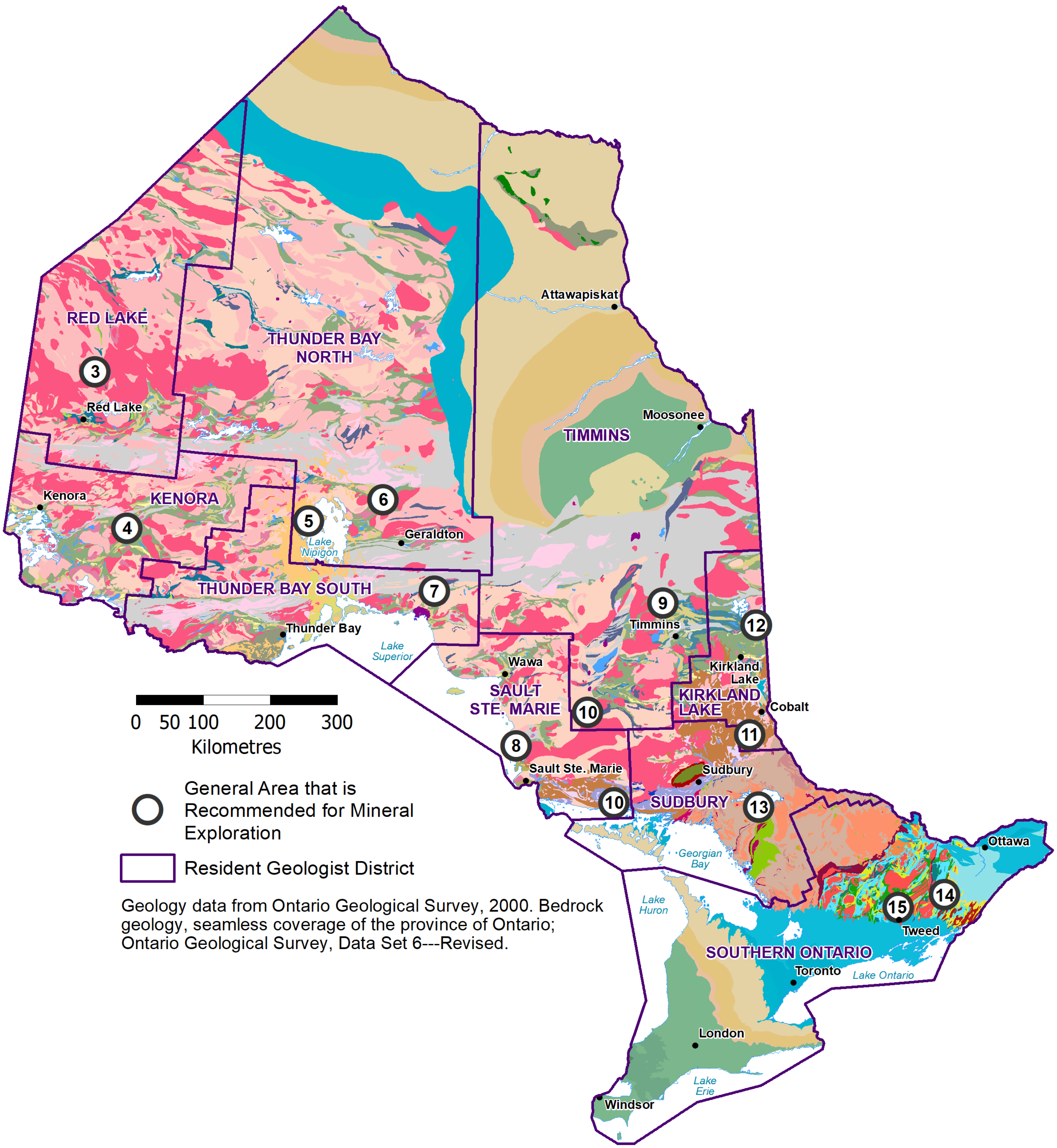
Ministry of Energy, Northern Development and Mines

Ontario Geological Survey - Resident Geologist Program

Ontario

ONTARIO CANADA

Recommendations for Exploration 2020–2021



Geology data from Ontario Geological Survey, 2000. Bedrock geology, seamless coverage of the province of Ontario; Ontario Geological Survey, Data Set 6---Revised.

ONTARIO CANADA

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Ontario Geological Survey
Resident Geologist Program
Recommendations for Exploration 2020–2021

The Ontario Geological Survey is pleased to issue its 2021 Recommendations for Exploration. These recommendations are the product of the Ministry of Energy, Northern Development and Mines' dedicated and knowledgeable staff located across the province.

Each year, recommendations are developed based on the wealth of geological and exploration data available to our staff (and you) and any new information or concepts derived from the current year's activities.

Please review our current recommendations and feel free to discuss these in detail with any of our geoscientists.

Visit OGSEarth on the Ministry's Mines and Minerals Division Web site (www.ontario.ca/ogsearth) to see what else is available.

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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 www.mndm.gov.on.ca/en/mines-and-minerals/geology#simple-table-of-contents-2 .

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

Contents

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:

Chadwick, P.C. 2021. Looking for gold in the eastern parts of the Kidd–Munro assemblage; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2020-2021, p.54-58.

HIGHLIGHTS

- **OGSFocus can be used by clients to identify areas that have seen considerable historical exploration and are currently available for acquisition**
- **Clients can use this product to streamline investigation of OGS databases for areas of interest**
- **OGSFocus emphasizes the importance of OGS–RGP data sets in area selection for mineral exploration**
- **The OGSFocus data product is available in both Google Earth and ArcGIS file format and includes 2 primary data sets: Data Rating Grid for Open Areas and Data Hot Spots**
- **OGSFocus also includes a separate Data Rating Grid for All Areas layer that also shows Data Scores for areas covered by active mining claims, leases and patents**

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OGSFocus: A New OGSEarth Layer to Quantify and Highlight OGS Mineral Exploration Data Sets

Overview

OGSFocus is a series of map layers that quantifies data from the Ontario Assessment File Database (OAFD), Ontario Drill Hole Database (ODHD) and Mineral Deposit Inventory (MDI) databases. A score based on the quantity of data available is assigned to each cell in the Mining Lands Administration System (MLAS) provincial grid along with a relative data rating. The resulting Data Rating Grids provide a visual representation of the quantity of data available. OGSFocus layers can be used as a targeting tool to draw attention to areas of considerable historical exploration including those available for acquisition. The Data Hot Spots layer highlights significant contiguous areas with robust data that are available for acquisition.

Data Sets

The OGSFocus data product is released in both *.kml* and *.shp* file format and includes 2 primary data sets: Data Rating Grid for Open Areas and Data Hot Spots, Table 1.

Table 1. Description of the primary OGSFocus data sets.

Data Set Name	Description
Data Rating Grid for Open Areas	A grid showing the amount of OAFD, ODHD and MDI data available in each cell and a rating relative to other cells in the Resident Geologist Program (RGP) District. This version excludes MLAS provincial grid cells that have active mining land tenure and includes only grid cells that are open for claim registration on the date of release. Attributes include the MLAS Cell Id, the number of features that overlap from each database and a data rating.
Data Hot Spots	Polygons that represent large, contiguous groups of grid cells that have comparatively high data ratings. Attributes include the area of the hot spot, the number of features that overlap from each database and a link to an online listing of these features.

An alternate version of the data rating grid, Data Rating Grid for All Areas, is updated on a monthly basis to coincide with MDI, ODHD and OAFD updates. Data Rating Grid for All Areas is similar to the 'Open Areas' version but does not exclude MLAS provincial grid cells that have active mining land tenure on the date of release.

Cundari, R.M. 2021. OGSFocus: A new OGSEarth layer to quantify and highlight OGS mineral exploration data sets; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2020-2021, p.1-5.

Technical Description

The Mining Lands Administration System (MLAS) provincial cell grid is used as a base grid for calculating the quantity of data for individual cells. The Ontario Assessment File Database (OAFD) polygon features, the Ontario Drill Hole Database (ODHD) point features and Mineral Deposit Inventory (MDI) database point features are considered to assess the robustness of the data overlapping tenure cells. Features that do not meet certain criteria are filtered out before processing (e.g., MDI points that are identified as Discretionary Occurrences, Overburden Drill Holes and Airborne Geophysical Surveys are omitted from the totals). A buffer distance of 200 m is applied to MDI points as mineral occurrences generally cover areas larger than a point location.

The number of features overlapping each of the available cells is counted and multiplied by a weighted value called the "Data Weight" (*see* Table 2 and Figure 2). These results are added together to give each cell a "Data Score" (*see* Figures 1 and 2). The Data Score gives an indication of the quantity of data available for a given cell (i.e., the robustness).

Table 2. The input/threshold variables and associated values considered in OGSFocus.

Input/threshold	Values
MDI buffer distance	200 m
Buffered MDI point weight	10
Drill hole weight	5
Assessment file weight	2
Data percentile threshold for Data Hot Spots	>85th
Area percentile threshold for Data Hot Spots	>85th

To assess the quality of data available and prioritize areas for targeting, a percentile threshold is applied to the Data Score. Percentile thresholds are generated individually for each RGP district to reflect the variable amounts of data that are available for different parts of the province. For simplicity, these percentiles are grouped into low, moderate, high and very high categories and colour coded accordingly (*see* Table 3 and Figure 3).

Table 3. Data Score percentiles and corresponding Data Rating values.

Data Score Percentile	Data Rating
<85	Low
85	Moderate
90	High
≥95	Very High

Two versions of the Data Rating Grid are available: Data Rating Grid for All Areas and Data Rating Grid for Open Areas. Data Rating Grid for All Areas displays Data Scores for all cells in the province with the exception of those overlying alienations, non-mining leases and dispositions, provincial parks and First Nation reserves. Any areas that are unavailable for claim registration including operational mining claims, mining leases and dispositions, alienations, provincial parks and First Nation reserves are removed from the Data Rating Grid for Open Areas data set. This results in a data set that shows all cells that are available for claim registration on the date of release.

To further highlight significant areas that have appreciable Data Scores, contiguous areas that display Data Scores in the 85th percentile or greater, and area sizes in the 85th percentile or greater, are identified as "Data Hot Spots". As with the Data Score percentile thresholds, Data Hot Spots for each RGP district are evaluated separately to reasonably represent the hot spot size and number for each individual district. Data Hot Spots are intended as a first pass approach to help focus the investigation into areas that have previously been deemed worthy of considerable investment and subsequent exploration. An OGSEarth image showing the Data Rating Grid for Open Areas, Data Hot Spots and a pop-up window showing information available for a selected Data Hot Spot is shown in Figure 4. OGSFocus can be downloaded in both *.kml* and *.shp* file format from the OGSEarth webpage.

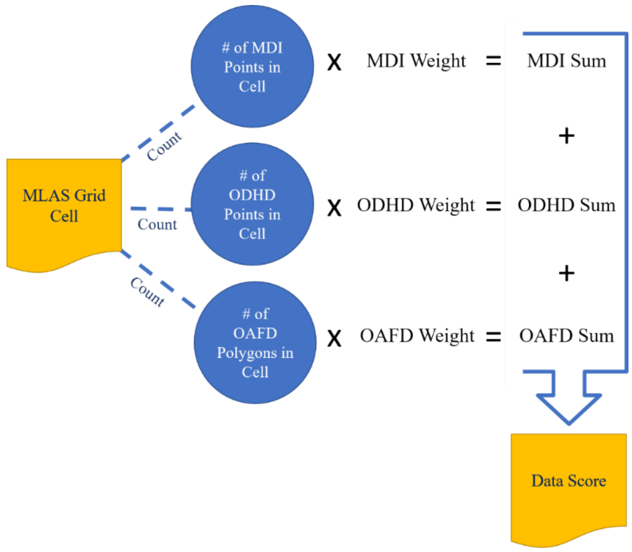

Figure 1. Flowchart showing the calculation process for the Data Rating Grid.

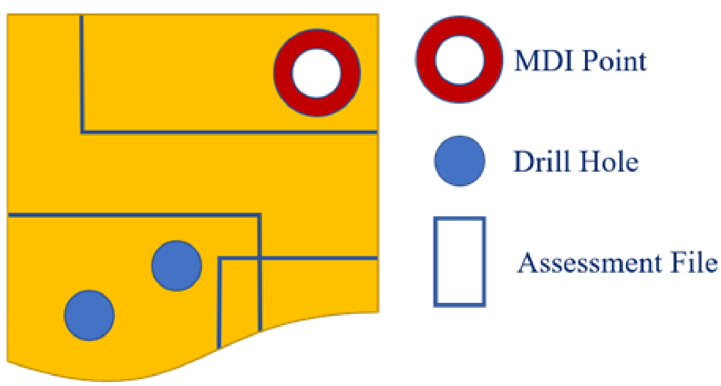

Figure 2. Example of a Data Score calculation for an MLAS tenure cell (Feature Count x Data Weight = Data Score): Example cell (yellow) intersects 3 Assessment Files (3 x 2 = 6), 2 Drill Holes (2 x 5 = 10), 1 MDI (1 x 10 = 10), Total Data Score = 26.

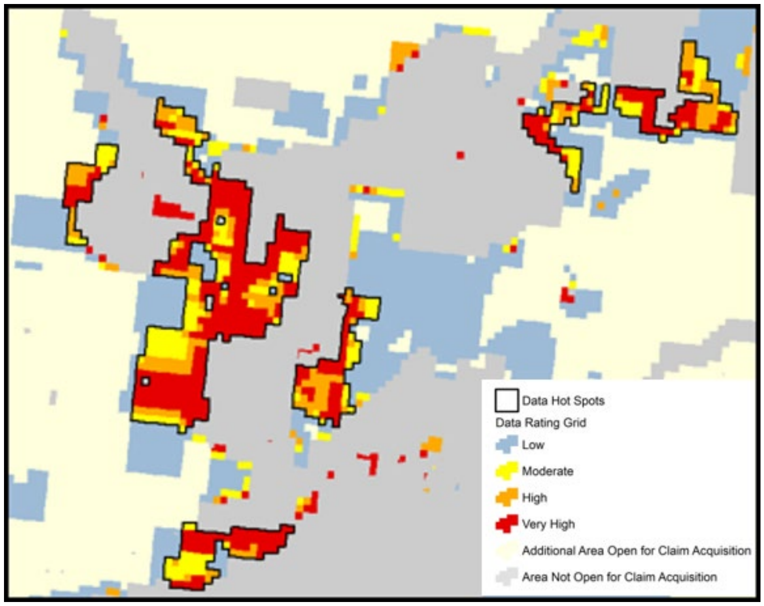

Figure 3. Simplified version of OGSFocus showing the Data Rating Grid for Open Areas (coloured grid) and the Data Hot Spots.

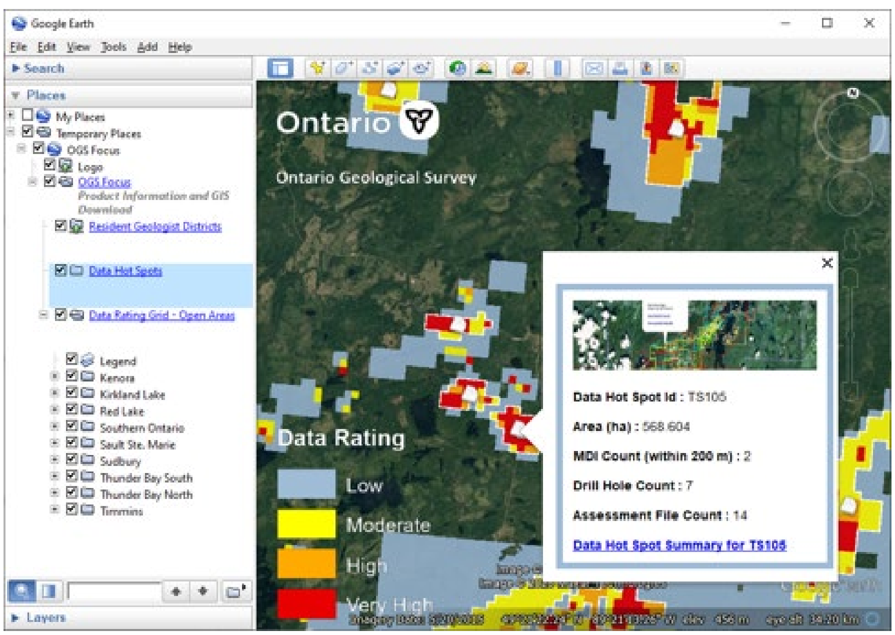

Figure 4. Example of OGSFocus in OGSEarth showing the Data Rating Grid for Open Areas (coloured grid), Data Hot Spots (white outlines) and the pop-up window containing available information for the selected data hot spot.

Disclaimer

The OGSFocus data sets are provided free of charge for information purposes only and are provided "as is" without warranties or conditions of any kind, either express or implied. In providing the OGSFocus data sets, the Ministry of Energy, Northern Development and Mines ("ENDM") and the Government of Ontario accept no liability and make no warranty or any representation regarding the use, accuracy, applicability, completeness, performance, availability, security or reliability of the information contained therein.

The OGSFocus data sets are provided to users on the basis of the best information available to ENDM at the time of its release. In particular, the Data Rating Grid is based on Mining Lands Administration System ("MLAS") data generated on the date of release. Users are advised to verify potentially available cells viewed in OGSFocus with the MLAS viewer to ensure that areas of interest generated by OGSFocus are open for acquisition in MLAS. OGSFocus data sets are generated by an automated process and are not reviewed or interpreted by ENDM before they are released.

OGSFocus is not a mineral potential estimation tool and the Data Hot Spots generated therein are <u>not</u> indicative of mineral potential and should therefore <u>not</u> be relied on by users to inform exploration decisions. ENDM and the Government of Ontario accept no liability and make no warranty or representations regarding the reliance on OGSFocus data sets for exploration decisions.

HIGHLIGHTS

- **Some mine tailings dams contain a large mineral resource**
- **There are many international examples of companies successfully mining tailings**
- **Potential for Ontario's closed and abandoned mines to contain economic tailings resource**

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Mine Tailings Dams are a Valuable Source of Minerals

Historically, mine tailings dams or tailings management facilities (TMFs) have been viewed as a liability, both from an environmental perspective and an aesthetic one. However, in recent years, TMFs have become considered as potential sources of minerals and as valuable commodities and there are many examples around the world where companies are mining TMFs. Given the number of closed and abandoned mines in Ontario, there is a high potential for the TMFs of many of these previous operations to hold economic resources of minerals.

Mining tailings is not a new concept. From 1989 until 1999, Kaltails mined the tailings dumps that had been generated from over 100 years of gold mining around the Golden Mile in Kalgoorlie, Western Australia. The tailings were hydraulically mined and the slurry was pumped to a dedicated mill where the tailings were treated in a carbon-in-pulp circuit. The mill was able to process 6.4 million tonnes of tailings per year. Over the ten-year operation of Kaltails, more than 60 million tonnes of tailings were reprocessed, with 695,000 ounces of gold being recovered. A total of 333 hectares of ground was reclaimed, with 262 hectares being subsequently used for waste rock deposition and the remaining 71 hectares being contoured and reseeded (Tailings.info, http://www.tailings.info/casestudies/kaltails.htm [accessed 19 November 2020]).

Why Mine a Tailings Dam?

There are a number of factors why mining a tailings dam makes economic sense. Many of the operations were mined in the late 19th and through the 20th Century and in that time, mill recoveries were lower than today. Canada Cobalt Works announced in March 2019 that they had created a silver-rich concentrate from gravity separation from a tailings dump located 300 m from the #3 shaft of the Castle Mine in Cobalt, Ontario. The concentrate graded 389 g/t Ag, 0.63 g/t Au and 0.2% Co (Canada Cobalt Works Inc., news release, 1st March, 2019).

Impala Canada's Lac des Iles palladium mine, north of Thunder Bay, Ontario, had an average recovery of around 80% between 2012 and 2018. For the production years 2014 through 2016, part of the mill feed was reprocessed tailings (North American Palladium Ltd., 2014 Annual Report, 13th May, 2015; 2015 Annual Report, 22nd February, 2016; 2016 Annual Report, 27th March, 2017).

Volcanogenic massive sulphide (VMS) deposits have traditionally been processed in high-throughput mills, rather than high-recovery mills. For example, the Century Mine in northeast Queensland, Australia, which had a resource of 118 Mt at 10.2% zinc, processed 7.0 Mt of ore per year at modest recoveries, averaging 74% in 2015 (New Century Resources Limited, https://www.newcenturyresources.com/century-mine-project/

Millar, R. 2021. Mine tailings dams are a valuable source of minerals; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2020-2021, p.6-8.

geology-resources/ [accessed 28th October, 2020]). The Hellyer polymetallic deposit on the west coast of Tasmania, Australia, had a reserve of 16.1 Mt grading 13.9% Zn and 7.1% Pb, along with 168 g/t Ag and 2.5 g/t Au (MinDat.Org, https://www.mindat.org/loc-19265.html [accessed 28th October, 2020]). The resulting 9.5 Mt tailings resource grades 2.5% Zn, 3.03% Pb, 104 g/t Ag and 2.61 g/t Au (NQ Minerals Plc, https://www.nqminerals.com/hellyer/ [accessed 28th October, 2020]). A simple mathematical calculation shows that the Zn recovery was 82% and the Pb was 57%, together with 38% Ag recovery.

In many cases, the company mining a deposit was focussed on the primary commodity, be it gold, base metals or industrial minerals and were either unprepared to extract secondary minerals from the ore, due to cost or lack of demand at the time, or because they were unaware of the presence of the secondary minerals.

In October 2019, Rio Tinto announced that analysis of the tailings at their borate mine in Boron, California showed it contained high grades of lithium and that they were building a pilot plant to treat the tailings and produce lithium carbonate. If the pilot is successful, they intend to build a commercial plant capable of producing 5,000 tonnes of lithium carbonate per year. Of interest in their discovery is that they weren't looking for lithium in the tailings – they were looking for gold – the lithium was a serendipitous discovery (Investing News, https://investingnews.com/daily/resource-investing/battery-metals-investing/lithium-investing/what-does-rio-tinto-eureka-moment-mean-lithium-supply/ 23rd October, 2019).

Canada Rare Earth Corporation is a Vancouver-based company that specializes in the supply chain for rare earth minerals. In February 2019, they announced that they had entered into a binding agreement to purchase 75 Mt of mineral sand tailings which contain economic quantities of rare earth elements (REEs). They intend to construct a reprocessing facility to treat the tailings and produce marketable REEs (Canada Rare Earth Corp., news release, 12th February, 2019).

International Examples

New Century Resources commenced retreatment of the tailings from the Century Zinc deposit in August 2018. The proven reserve on the tailings deposit is 77.3 Mt at 3.0% zinc and 12.0 g/t silver. The operation is ramping up to nameplate capacity to produce 500,000 tonnes per annum of zinc concentrate and the estimated mine life for the tailings retreatment is 6.5 years (New Century Resources Limited, https://www.newcenturyresources.com/century-mine-project/restart-feasibility-study/ [accessed 28th October, 2020]).

NQ Minerals Plc's Hellyer polymetallic deposit produced its first shipment of concentrate from tailings in September 2018 (NQ Minerals Plc., news release, 12th November, 2019) and achieved full commercial production by the end of 2018 (NQ Minerals Plc., news release, 15th January, 2019). The company produces 3 streams of concentrate: a lead, gold and silver concentrate; a zinc concentrate; and a precious metal—pyrite concentrate (NQ Minerals Plc., News release, 22nd May, 2019). The total tailings resource for the deposit is 9.5 Mt grading 2.5% Zn, 3.03% Pb, 104 g/t Ag and 2.61 g/t Au. Estimated mine life is 10 years (NQ Minerals Plc., news release, 31st May, 2019).

Jubilee Metals Group Plc is a South African-based company which specializes in metals recovery from mining waste. They currently have 5 operations in southern Africa recovering lead, zinc, vanadium, chromium and platinum group elements from mine tailings. Their current project targets are tailings facilities in mature jurisdictions, predominantly sub-Saharan Africa, Australia and South America (Jubilee Metals Group Plc, https://jubileemetalsgroup.com/corporate-profile/ [accessed 28th October, 2020]).

Tailings Reprocessing Pros and Cons

There are a number of pros and cons with respect to tailings reprocessing.

Among the pros are the fact that the tailings have already been mined, crushed and milled and are generally altogether in a single or closely linked multiple TMFs. The mining of these facilities can involve hydraulic mining and pumping to a mill, dredging and pumping or utilizing loaders and trucks to move the material. Thus, the mining cost is very low.

In the case of New Century and Hellyer, the mills were still intact and on-site and could be modified for the treatment of tailings for little capital outlay. The start-up costs for Hellyer were the equivalent of C$20M (£12M) (NQ Minerals, news release, 31st May, 2019), while the start-up capital costs for New Century were the equivalent of C$44.6M (AUD$50M) (New Century Resources Limited, https://www.newcenturyresources.com/century-mine-project/restart-feasibility-study/ [accessed 28th October, 2020]). These costs are substantially lower than the start-up cost of a new hard rock operation.

Production can be brought online very quickly, as there are not the usual time constraints that are associated with developing a new mine – no overburden stripping or ramp development to access the ore. With respect to the Hellyer deposit, it was brought into production within a nine-month period from when refurbishment of the Hellyer mill commenced (NQ Minerals Plc., news release, 31st May, 2019).

The reprocessing of tailings can have a positive environmental impact on former mine sites and help reduce the financial liabilities associated with them. In the case of Kaltails, 333 hectares of ground was reclaimed, with 262 hectares subsequently being used for waste rock dumps and 71 hectares being recontoured and reseeded (Tailings.info, http://www.tailings.info/casestudies/kaltails.htm [accessed 28th October, 2019]). In the case of New Century, the retreated tailings will be deposited in the Century open pit in a subaqueous environment. This will negate the need to cap the current tailings dam on surface and will significantly reduce the overall disturbance footprint on the site, which the company hopes will lead to a reduction in the current financial assurance for the site (New Century Resources Limited, https://www.newcenturyresources.com/century-mine-project/ [accessed 28th October, 2020]).

However, mine tailings also come with certain risks and liabilities. Many old mine sites have substantial environmental liabilities associated with them and large financial assurances. Depending on the status of the mine in question, the proponent would have to negotiate an option agreement with the current owner which would likely entail having to assume both the environmental liability and taking over the financial assurance for the property. As such, the proponent would need to be confident of the economics of the project and the financial backing to undertake the project. If the property is a legacy project, in that the Government of Ontario is now the vested owner of the site, then there would be negotiations with the government's representatives to consider.

To the best of the author's knowledge, there have been no attempts to mine tailings from a closed mine in the province of Ontario since the late 1980s. Therefore, there might be a number of regulatory procedures to follow to undertake the project. As this is an untested area, there is no indication of the timeframe required to move a project from conception to production.

Any proposal to mine tailings would require updating the mine closure plan for the property in question. This would require regulatory review, the possibility of certain requirements or restrictions placed on the proposal and a review of the financial assurance.

Any proposal would require consultation with affected stakeholders. This could include First Nations communities, Métis organisations, municipalities and local landholders.

Conclusion

While there are a number of unknowns regarding the possibility of mining tailings in Ontario for economic benefit, there are a number of international examples that demonstrate the viability of these projects. These companies would also be a useful resource for information in how they achieved their goals.

There are multiple closed and abandoned mines in Ontario that potentially have large economic resources sitting in tailings facilities awaiting reprocessing.

HIGHLIGHTS

- **A deep tapping seismic structure with surface represented shear zones**
- **Underexplored area with gold mineralization potential**
- **Intermediate and mafic metavolcanic rocks present within the South Arm area**
- **Excellent access**

Deep Tapping Seismic Structure in the Red Lake District

The Red Lake District hosts several high-grade gold mines and exploration projects that sit at or near deep-tapping seismic structures.

A seismic survey interpretation was completed by Fafu Zeng on the Western Superior Line 2b as part of his requirements for a Master's degree at Simon Fraser University (Zeng and Calvert 2011). Mr. Zeng's interpretation identified several deep-tapping seismic zones that surface near mining and exploration operations within the Red Lake District.

The Red Lake gold mine, owned and operated by Evolution Mining Inc., is a high-grade orogenic gold mine. Gold mineralization in the Red Lake area typically occurs in veins, lenses, fractures and hinge zones hosted in deformed metamorphic rocks (Sanborn–Barrie et al. 2004). Orogenic gold deposits are often associated with second or third order deformation zones that may illustrate distinctive seismic reflections and character. Zeng and Calvert (2011) identified seismic reflections which correspond to the Red Lake Mine trend and the unconformity boundary between the Balmer and Confederation assemblages (Figure 1).

The Dixie Lake property, owned and operated by Great Bear Resources Ltd., is a prospective exploration project that sits near another deep-tapping seismic structure (Figure 2). Company geologists believe (Great Bear Resources Ltd., investor presentation, October 2020) that the LP Fault zone sits near the seismic structure boundary between the Confederation assemblage and the metasedimentary rocks of the English River Subprovince as interpreted by Zeng and Calvert (2011). Furthermore, strong shear fabrics and highly strained rocks are observed from the drill core at the LP Fault zone (Great Bear Resources Ltd., news release, 28 September 2020).

Unfortunately, the interpretation by Zeng and Calvert (2011) did not include the northern-most parts of the Western Superior Line 2b. However, further examination of the seismic profile suggests the presence of a third deep-tapping seismic structure in the northernmost parts of Western Superior Line 2b transect (Figure 3), in the vicinity of the South Arm of Berens Lake. Preliminary mapping of the South Arm area completed by Buse (2007) identified felsic and mafic volcanic rocks, felsic to mafic intrusive rocks, and metasedimentary rocks. Buse (2007) also identified a shear zone which corresponds to the hypothetical location of the deep-tapping seismic structure (*see* Figure 3).

Buse (2007) collected 31 rock samples in the South Arm area. Only 16 of these samples were assayed for gold with no significant values obtained. However, pyrite and pyrrhotite mineralization, and garnet, sillimanite and epidote alteration was identified from several samples in the vicinity of the shear zone.

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Lewis, S.O. 2021. Deep tapping seismic structure in the Red Lake district; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2020-2021, p.9-13.

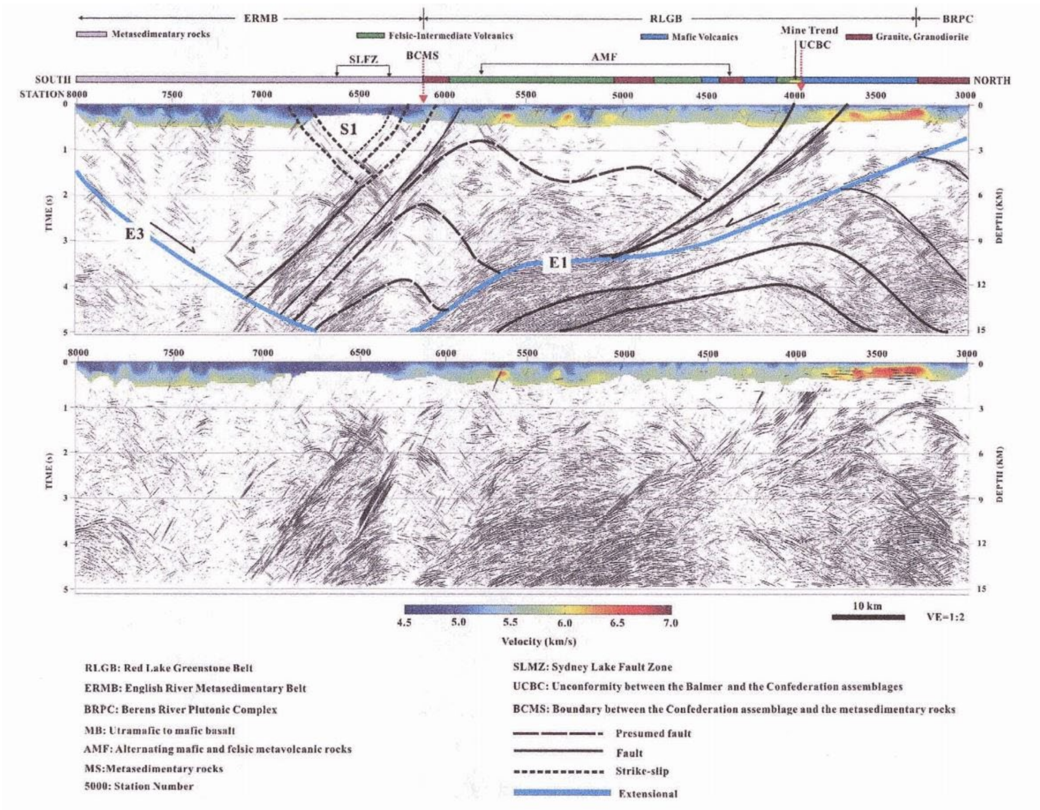

Figure 1. The integrated interpretation of the combined tomographic and reflection profile by Zeng and Calvert, 2011. The Red Lake mine trend, unconformity between Balmer and Confederation assemblages are located on the right center of the profile cross section. The seismic reflection which represents the LP Fault zone location are labeled BCMS (boundary between Confederation and Metasedimentary Rocks)

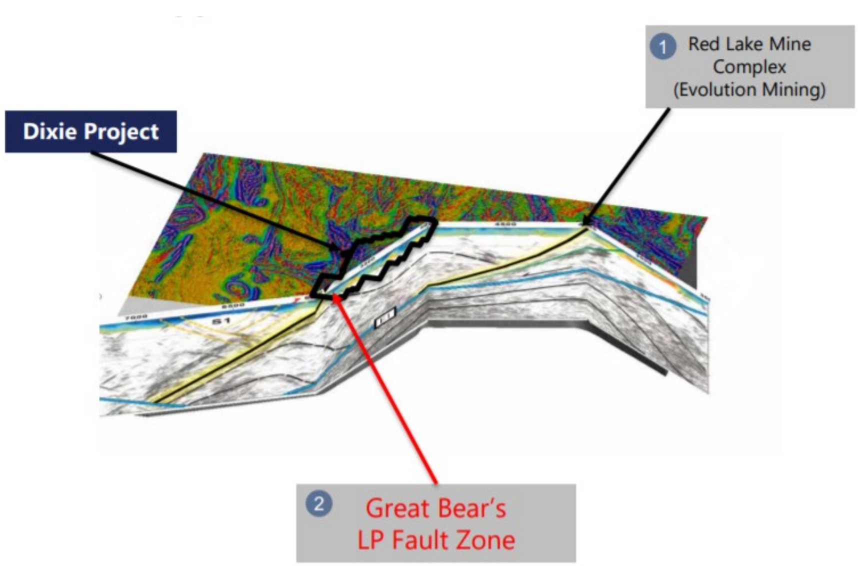

Figure 2. Pseudo cross-section of the seismic survey illustrating the proximity of the LP Fault zone to deep-tapping seismic structure identified by Zeng and Calvert (2011) (Great Bear Resources Ltd., Corporate Presentation, October 2020).

During the 2019 field season, Red Lake Resident Geologist Program staff attempted to find the surface representation of the seismic structure, mafic volcanic rocks, and an overburden gold anomaly that was reported by Agnico Eagle Canada (2010). Field data that were collected included outcrop photos, traverse route tracks and a rock sample (2019SL01). The float sample was submitted to the Ontario Geological Survey Geoscience Laboratories (Sudbury) for precious metal assays and returned a value of 1.02 g/t Au. The gold-bearing sample was dark grey, fine-grained and fractured, containing disseminated pyrite mineralization and minor fracture-fill carbonate alteration. Unfortunately, no outcrop showing of this rock type was observed, but Stone and Good (1990) mapped the geology of this sample location as mafic metavolcanic rocks characterized as amphibole gneiss. Additionally, this grab sample location is near the hypothetical surface representation of the third seismic structure and is along strike with the shear zone mapped to the northeast by Buse (2007).

An overburden sampling program by Agnico Eagle Canada Ltd., provides the only assessment file within this region (Villeneuve and Girard 2010). This overburden sampling program identified several anomalous gold values in the South Arm area. A gold anomaly above the 99th percentile was located very near the grab sample collected by the Resident Geologist Program in 2019 (Figure 4). A second gold anomaly above the 95th percentile was collected near the shear zone identified by Buse (2007) (*see* Figure 4).

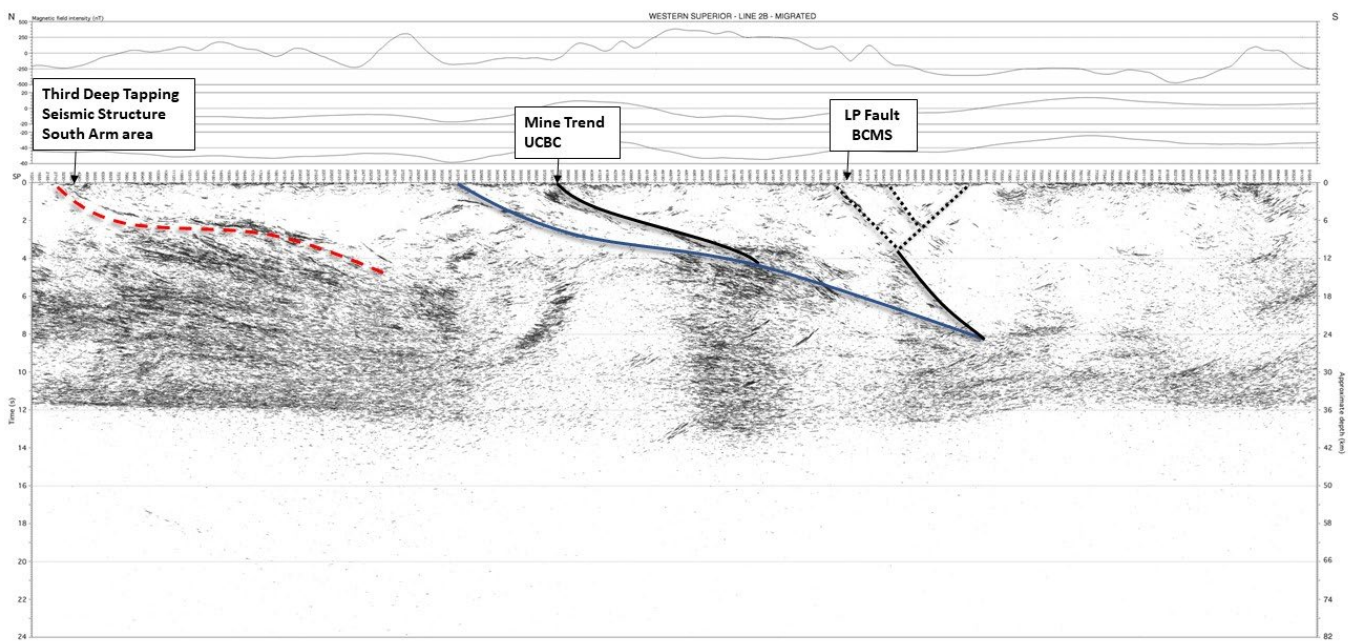

Figure 3. Original uninterpreted seismic survey of the Western Superior Line 2b with features added from Zeng and Calvert (2011). The blue solid line is the extensional fault identified as "E1' from Zeng and Calvert (2011). The solid and dashed black lines are the seismic faults. UCBC–Unconformity between Confederation and Balmer assemblages. BCMS–Boundary between Confederation rocks and metasedimentary rocks. Note that the UCBC and BCMS sit at or near significant mining or mineral exploration projects, specifically the Red Lake gold mines owned and operated by Evolution Mining Inc., (also known as Mine Trend) and the LP Fault zone owned by Great Bear Resources Ltd. A third deep-tapping seismic structure exists and is identified by the dashed red line and appears to surface near the South Arm area.

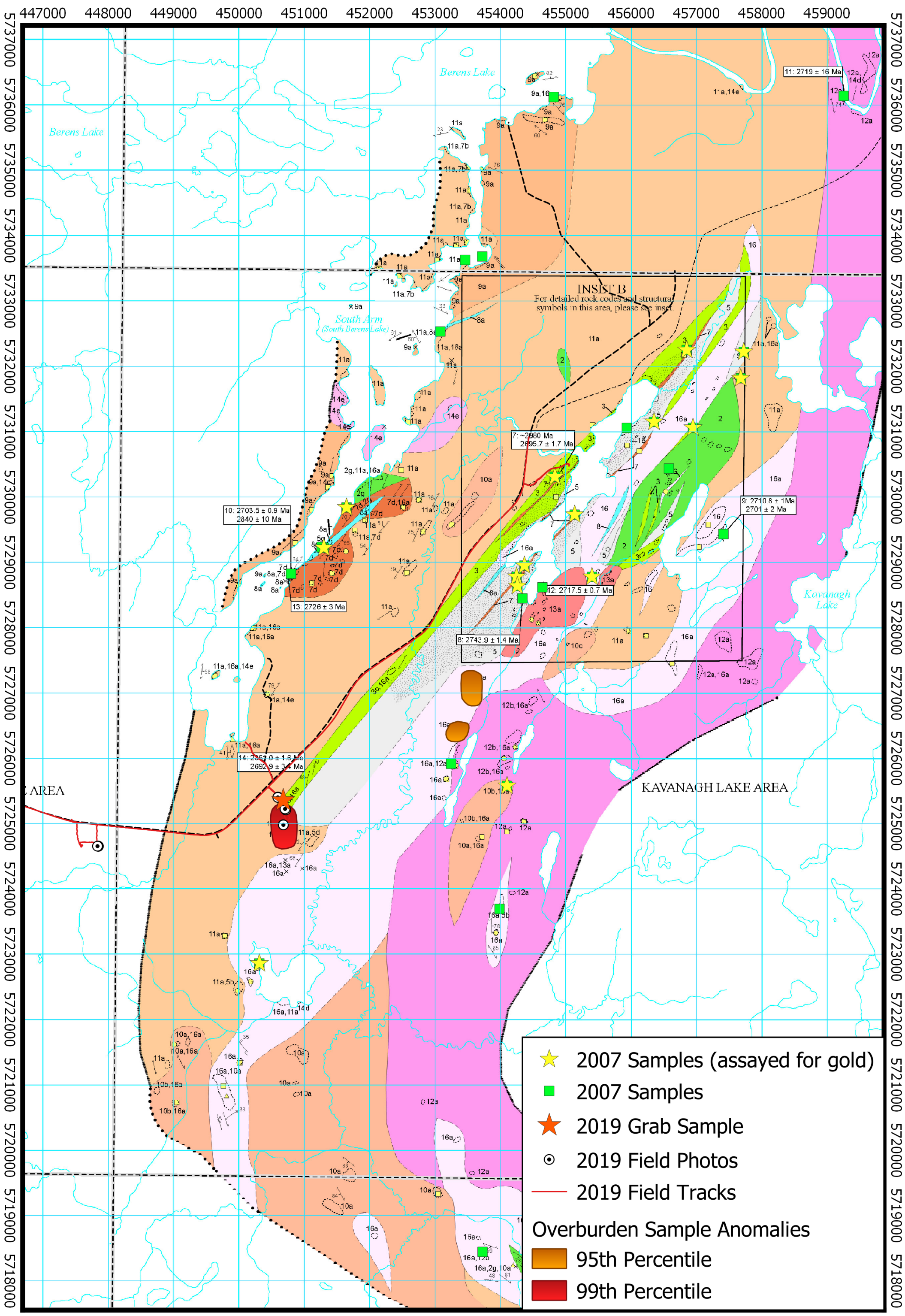

Figure 4. Precambrian geology map *from* Buse 2007. Grab sample (overburden) was collected in the South Arm area, southwest of the northeast trending shear zone mapped by Buse (2007) and is in the immediate area of the soil anomaly identified by Agnico Eagle Canada.

Summary

The Berens Lake South Arm area is interpreted to be the location of a deep-tapping seismic structure. Such structures have a close relationship to gold mining and mineral exploration within the Red Lake District. The South Arm area has received very limited historical exploration interest but has some very encouraging characteristics that indicate the presence of excellent opportunities for the discovery of gold mineralization. The identification of a deep-tapping seismic structure that correlates with shear zones from preliminary geological mapping indicates the potential existence of a conduit for migrating gold-bearing fluids. A pyrite-bearing carbonate altered grab sample containing 1.02 g/t Au and 2 overburden samples above the 95th and 99th percentile for gold provides evidence that gold mineralization exists within the South Arm area and makes it an interesting gold exploration target area.

References

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HIGHLIGHTS

- **Seven-year, $104 million mineral exploration research and development program**
- **Three transects located in Western Wabigoon subprovince**
- **Integrated craton-scale transect, thematic and data analysis research could identify mineral potential areas**

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Metal Earth Program Research in the Kenora District

Metal Earth is a seven-year, $104 million applied research and development program that is led by the Mineral Exploration Research Centre (MERC), part of the Harquail School of Earth Sciences based at Laurentian University in Sudbury, Ontario. The program received funding in 2016 with field work commencing in 2017 (Mineral Exploration Research Centre 2018a).

In order to reveal the fundamental geological processes that were responsible for the formation of mineral deposits in the Superior Province, MSc, PhD students, research associates and field assistants will be conducting research for Metal Earth projects across northern Ontario and Quebec (Figure 1). Three of these transects are located in the Kenora District (Figure 2).

In 2017, transect-scale data collection from seismic reflection surveys was completed along the 3 transects within the Kenora District (*see* Figure 2). In 2018, magnetotelluric (MT) surveys utilizing broadband MT and audio MT techniques were also completed along the 3 transect lines. Magnetotelluric data is often acquired in conjunction with seismic reflection surveys to provide additional information on subsurface structure or lithological stratigraphy.

Thematic and data analytical research has been initiated within the area surrounding the 3 transects (*see* Figure 2). Frieman (2018) mentions that “the supracrustal stratigraphy, intrusive history, structural evolution, and metamorphic development are largely under-investigated, and their relationships with economic resource distribution are unknown. This project aims to investigate and integrate these topics to propose a revised Precambrian and metallogenic evolution model of the Western Wabigoon”.

Field work at the transects completed to date has focused mainly on regional lithological contact relationships, geochemical, and geochronological relationships between volcanic rock types. Research Associates Ben Frieman, Gaetan Laundry and Chong Ma are team leaders for the Stormy–Dryden, Rainy River and Sturgeon Transect areas, respectively (Mineral Exploration Research Centre 2020a). This field work has involved regional lithological sampling, detailed geological mapping and the initiation of academic research studies ranging from the BSc to PhD level.

Ravnaas, C. 2021. Metal Earth program research in the Kenora District; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2020-2021, p.14-17.

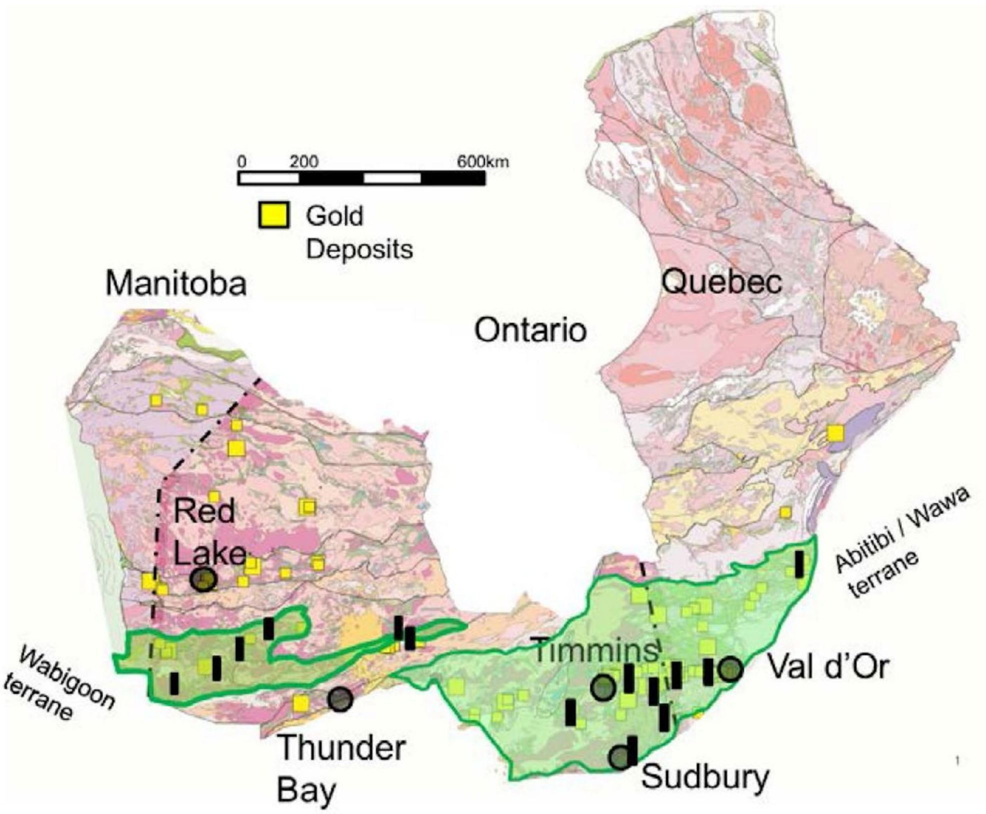

Figure 1. Geological compilation of the Superior Craton showing the Metal Earth transects (black bars), geological terranes (green shading) and selected communities (circles), *from* Mineral Exploration Research Centre 2018b.

The studies completed at each transect will focus on:

- The stratigraphy of the Archean metavolcanic rocks of the various volcanic assemblages;
- Structural or stratigraphic relationships between the assemblages;
- Nature and timing of deformation;
- Origin and timing of granitic magmatism;
- Origin and timing of volcanism;
- Sedimentary provenances of successor basins;
- Amalgamation of the metavolcanic assemblages, and
- Controls of metal endowment.

(https://merc.laurentian.ca)

Field work and research analysis combined with seismic and magnetotelluric survey results will be used by Metal Earth to update the synthesis of the Western Wabigoon subprovince. This data will be used to develop a new geodynamic model for its formation which will be compared to other mineralized belts in the Superior Province. These concepts, developed during and at the conclusion of the program, could provide valuable information which can be used to determine areas to evaluate for mineral potential. Therefore, individuals and companies engaged in mineral exploration activities in the Kenora District are encouraged to keep up to date on the progress, research presentations, maps and geoscience data of these ongoing Metal Earth research projects (Mineral Exploration Research Centre 2020b).

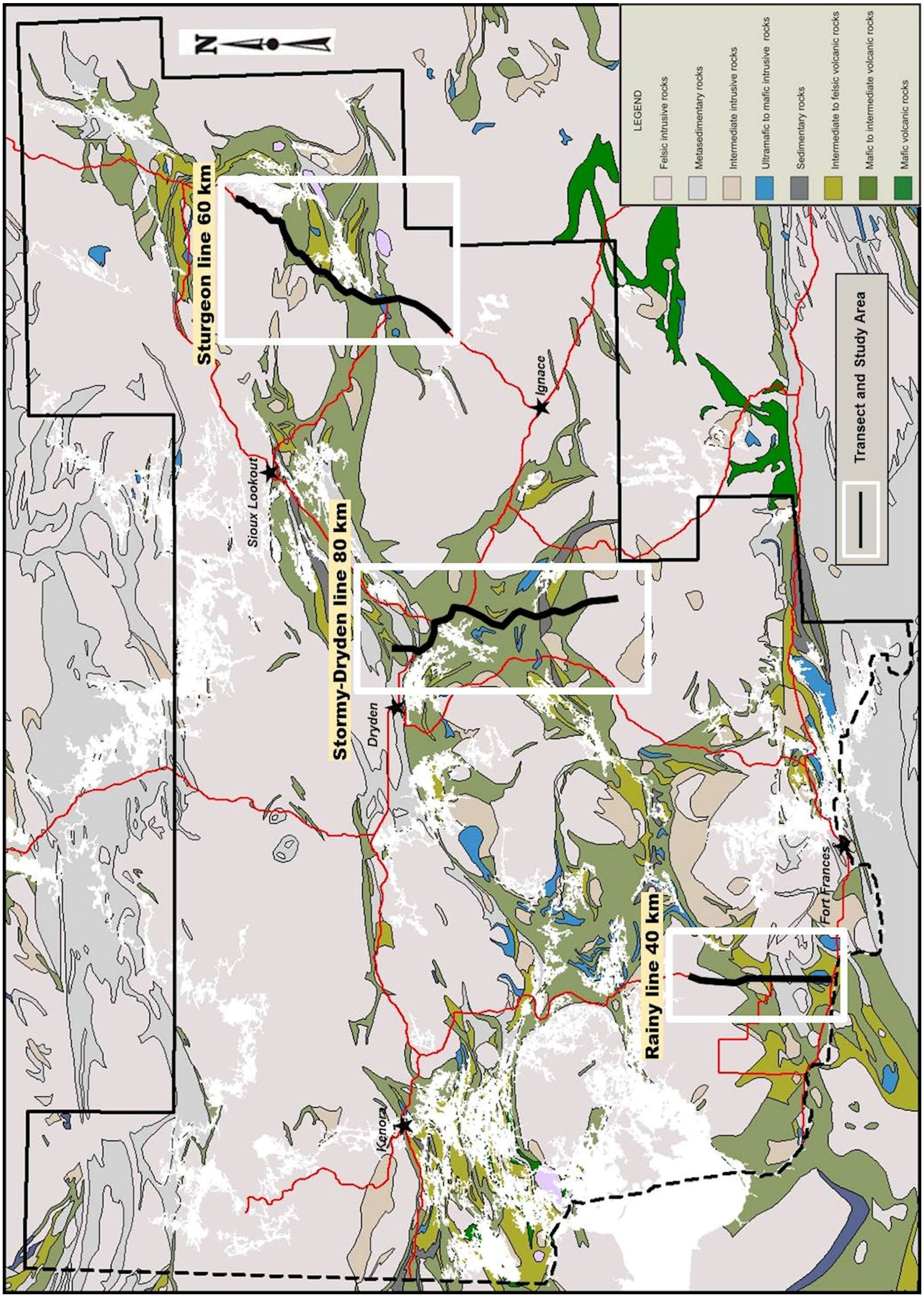

Figure 2. The 3 Wabigoon study transects (white boxes), located in the Kenora District, are outlined on bedrock geology (bedrock geology *from* Ontario Geological Survey 2011).

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HIGHLIGHTS

- **The English Bay Complex has many characteristics that are consistent with IOCG mineralization potential including moderate to strong hematite, sericite and silica alteration and elevated rare earth element contents**
- **The English Bay and Badwater complexes represent the Geon15 time period which is potentially prospective and underexplored for IOCG style mineralization**
- **Investigation into the association between late, oxidized, mantle-derived plutonic activity and gold mineralization of many Archean and potentially Proterozoic gold mineralizing systems (i.e., IOCG and/or porphyry-type) may increase the potential for significant discovery**

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Unconventional Gold Exploration Targets: IOCG and Oxidized Felsic Intrusions

IOCG Targets West of Lake Nipigon

Iron oxide-copper-gold (IOCG) deposits are a much desired but relatively elusive deposit type in Ontario. Iron oxide-copper-gold deposits are characterized as vein and breccia-hosted mineralizing systems that contain disseminated copper + gold ± silver ± palladium ± platinum ± nickel ± uranium ± light rare earth element mineralization with abundant hematite and/or magnetite (Cox and Singer 2007). Iron oxide-copper-gold deposits are formed in sedimentary or volcano-sedimentary basins intruded by igneous rocks and typically display broad redox boundaries with associated sodic alteration of source rocks and potassic alteration of host rocks. Although there are currently no recognized examples of IOCG deposits in the Lake Nipigon region, the potential for their discovery in this area has long been recognized (cf. Sutcliffe and Greenwood 1985; Smyk and Franklin 2007).

The 1546.5 ± 3.9 Ma English Bay Complex (EBC) covers an area of approximately 80 to 85 km^2 and consists of a granite-rhyolite assemblage outcropping on the western shores of Lake Nipigon (Hollings, Fralick and Kissin 2004; MacDonald 2004; Heaman et al. 2007). Davis and Sutcliffe (1985) describe the EBC rocks exposed at Redstone Point as anorogenic (A-type) granites gradational to rhyolites, and fragmental rhyolites and dacites whereby preserved outcrop on the shores of Lake Nipigon indicates that extrusive members dominate the magmatic rocks of the area. Hollings, Fraleck and Kissin (2004) suggested that the anorogenic EBC was derived from a mantle plume and it recorded the northern portion of a Mesoproterozoic plume track which produced anorogenic granites throughout North America. The potential for the EBC to host IOCG mineralization was first noted by Sutcliffe and Greenwood (1985) who stated that "The fluorite-bearing subvolcanic porphyry to granite intrusion on English Bay has not been previously recognized and warrants exploration for gold". MacDonald (2004) also noted that several areas within the Nipigon Embayment may have potential to host IOCG deposits including the EBC. The EBC has many features that suggest IOCG mineralization potential, including the presence of anorogenic granite with locally moderate to strong hematite, sericite and silica alteration, as well as elevated zirconium, yttrium and rare earth element contents (Sutcliffe 1991; Schnieders et al. 2002).

Cundari, R.M. 2021. Unconventional gold exploration targets: IOCG and oxidized felsic intrusions; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2020-2021, p.18-23.

Smyk and Franklin (2007) further cited the IOCG potential of the EBC as follows.

> Although no unqualified examples of the iron oxide-coper-gold (IOCG) deposits type have been located in the Lake Nipigon region, there have been recent discoveries of rare-earth element-rich zones southwest of Armstrong, which contain 6000-8000 ppm Zr, 1500-2000 ppm Nb and 1000-3000 ppm Ce in distinctly oxidized granite (East West Resource Corporation, Annual Report, 2005). This area is just west of the English Bay intrusive complex, a 1.54 Ga hypabyssal intrusion with some similarities (including age) to intrusions in the North American Midcontinent region (i.e., Ozark Mountains to Wisconsin) that have IOCG-style occurrences or mines associated with them (Pratt and Sims 1990).

The EBC shows both temporal and geochemical similarities to the nearby the Badwater Intrusive complex (BIC). Based on similar trace element geochemistry, the EBC was derived from a similar source to the nearby BIC syenites that were emplaced at 1590.1 ± 0.8 Ma (Heaman et al. 2007; Cundari, Smyk and Hollings 2014). The EBC and the BIC represent rocks emplaced in the Geon15 time period and represent the only intrusive rocks north of Lake Superior known to have been emplaced in this time period. The age of the EBC is broadly consistent with that of the large Olympic Dam IOCG deposit in Australia (ca. 1590 Ma; Johnson and Cross 1995) and several intrusions in the United States which host IOCG style occurrences or mines, as mentioned above (cf. Pratt and Sims 1990). It is plausible that other alkalic granitic bodies in the Lake Nipigon and broader Lake Superior region are related to this event and may represent prospective targets for IOCG style mineralization.

The limited amount of mineral exploration that has occurred in the EBC to date has confirmed the area's IOCG potential. Exploration efforts in 1997-1999 included prospecting, geological mapping, soil geochemical sampling, stream sediment sampling, and lithogeochemical sampling by R.J. Dean identifying several elevated metallic and rare earth element values from grab samples (Dean and Kathmann 1997). Corona Gold Corp. optioned the property and completed a helicopter-borne magnetic, radiometric and electromagnetic survey of the property, totalling 772 line-km as well as 5 diamond-drill holes totalling 2650 m (Wood and Drost 1998). Detailed accounts of the results from these exploration programs can be found in the Thunder Bay North Report of Activities for 1997 (Mason et al. 1998) and 1999 (Mason et al. 2000) as well as various assessment files available through the Ontario Geological Survey online data warehouse, *GeologyOntario* at www.ontario.ca/geology.

From 1999 to 2006, East West Resource Corp. completed several exploration programs targeting potassium-, uranium- and thorium-anomalous zones in the EBC and BIC areas that may reflect IOCG (referred to by East West Resource Corp. as Olympic Dam-style mineralization; Middleton, Tweedie and Baker 2001). Several zones of drill core anomalous in rare earth elements were discovered in alkalic granitic rocks suggestive of a favourable environment for IOCG style mineralization. Summaries of those activities can be found in the Thunder Bay North Report of Activities for 2003 (Smyk et al. 2004), 2004 (Smyk et al. 2005) and 2005 (Smyk et al. 2006) as well as various assessment files available through the Ontario Geological Survey online data warehouse, *GeologyOntario* at www.ontario.ca/geology.

Oxidized Felsic Intrusion Targets in the Onaman–Tashota Greenstone Belt

Proximity to magnetic felsic intrusions has been noted for many Archean gold occurrences in the Superior Province, including some in the Eastern Wabigoon Subprovince. Hattori (1987) suggested that magnetite-rich felsic intrusions and the identification of oxidized magmatic-hydrothermal alteration may aid in targeting favourable areas for Archean gold deposits. Hattori (1987) cites the following gold deposits in the Onaman–Tashota greenstone belt (in the Eastern Wabigoon Subprovince), which occur near the contacts of and/or within felsic stocks:

- the Quebec Sturgeon Mine (Elmhirst Lake and Coyle Lake stocks);
- the Mitto and Greenoaks deposits (Elmhirst Lake stock); and
- the Dik-Dik/Orphan Mine (Kaby Lake stock).

Beakhouse (2007) further proposed a magmatic-hydrothermal model for Archean lode gold that suggests the timing of gold mineralization is synchronous with late-stage plutonic activity, regional metamorphism and the later stages of regional deformation. Plutons that are emplaced synchronously with this main stage gold introduction event are those associated with the late, mantle-derived (sanukitoid and alkalic) suites which are often anomalously oxidized. Beakhouse (2007) further suggests that magmatic-hydrothermal fluids are primarily responsible for the generation of a subset of Archean lode gold deposits and are a major to minor fluid component within other deposits. Many intrusions present in the Wabigoon Subprovince, particularly those mentioned in the Onaman–Tashota greenstone belt, resemble the late, oxidized, mantle-derived plutons described by Beakhouse (2007). Further work is warranted in the Eastern Wabigoon and elsewhere in the Superior Province, to establish the relationship between gold mineralization and late-stage plutonic activity.

While the Archean magmatic-hydrothermal gold models of Hattori (1987) and Beakhouse (2007) are definitely applicable to the Onaman–Tashota greenstone belt, the potential for discovery of Proterozoic IOCG type gold mineralizing systems in this area should not be discounted given the potential for previously unrecognized Geon15 magmatism in the Lake Nipigon region.

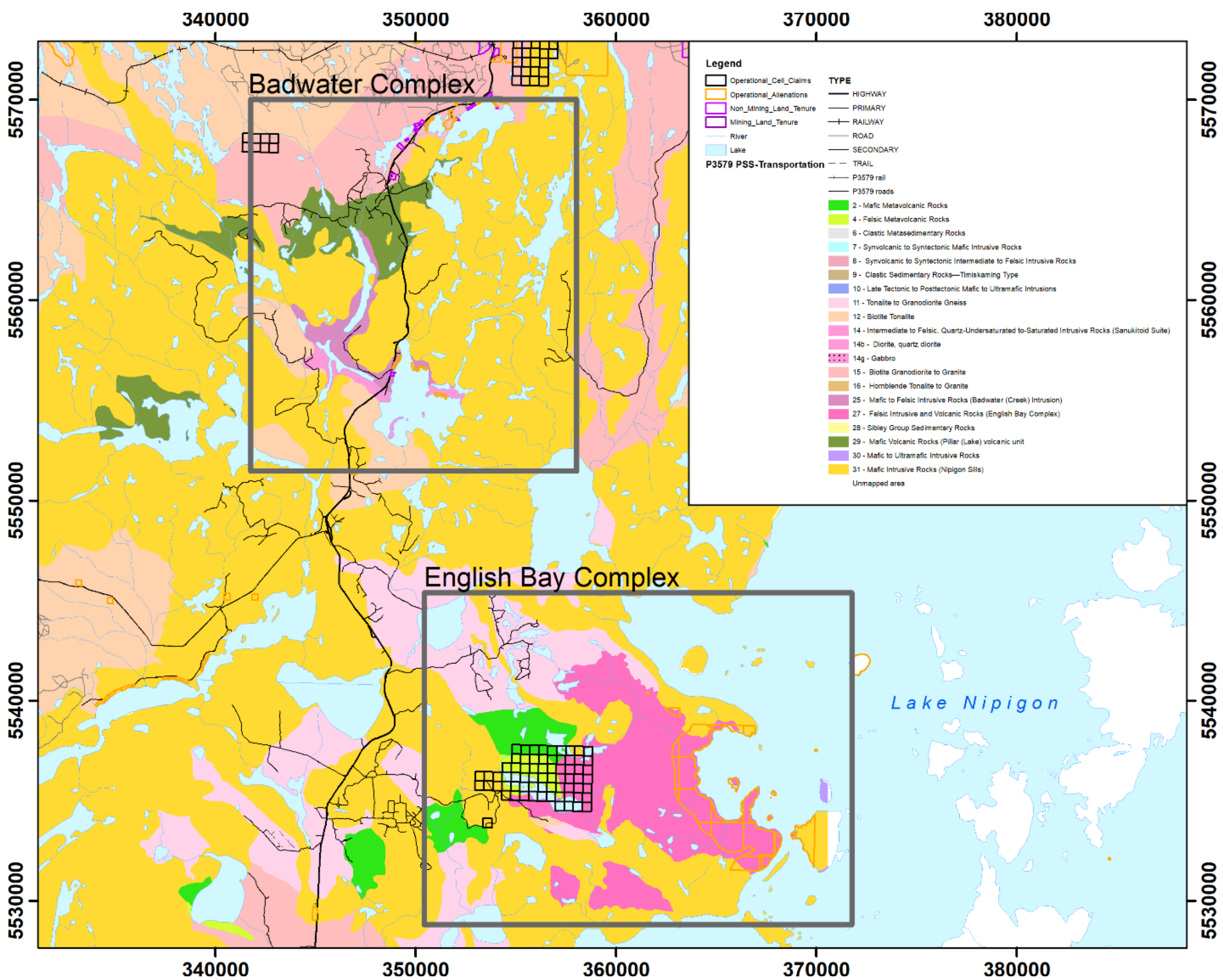

Figure 1. Geological map of the northwest Lake Nipigon area showing the approximate locations of the English Bay and Badwater intrusive complexes in the Thunder Bay North District. Geology *from* Hart (2006). UTM co-ordinates in NAD83, Zone 16. Claim units as of December 15, 2020.

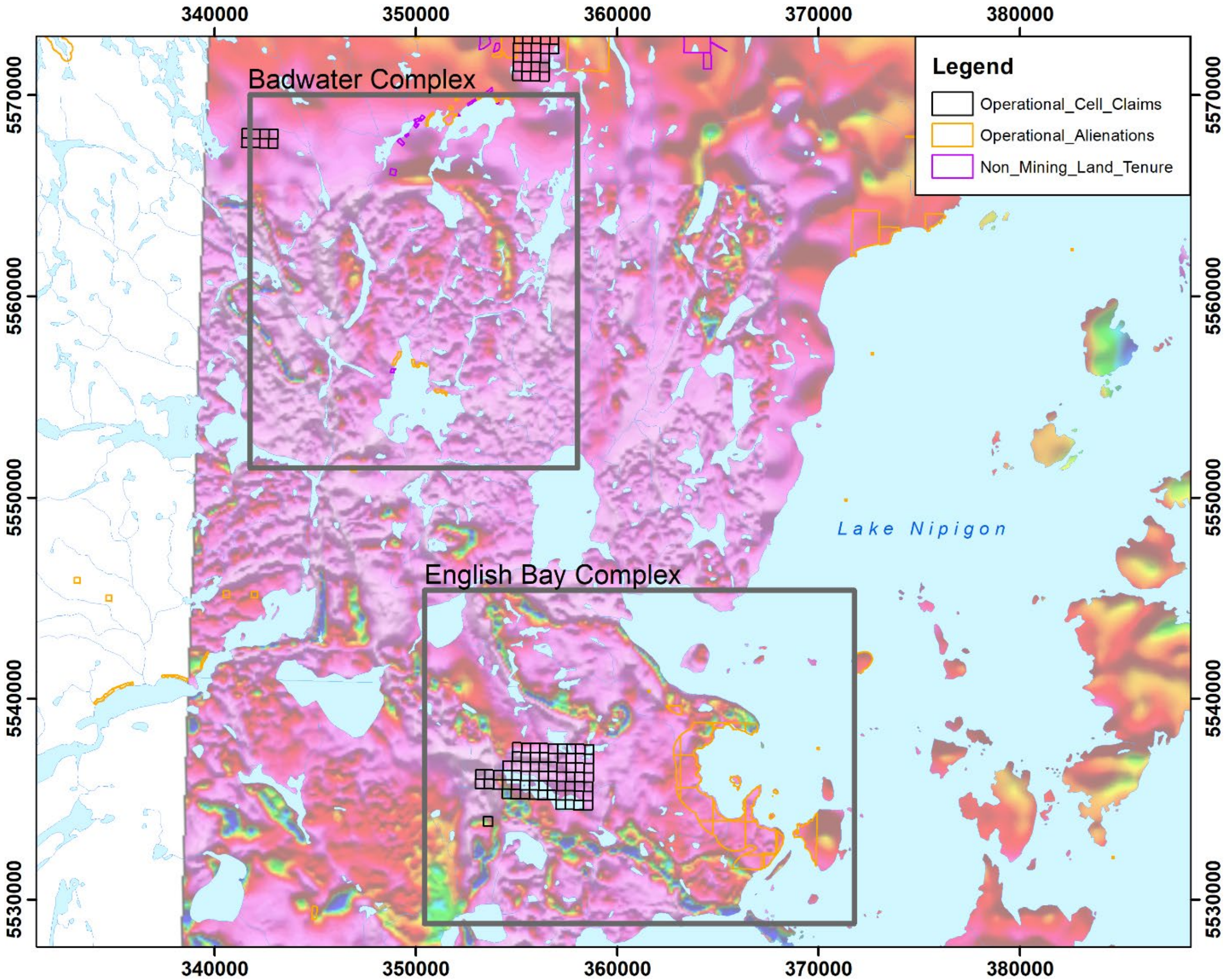

Figure 2. Total field magnetic imagery map of the northwest Lake Nipigon area showing the approximate locations of the English Bay and Badwater intrusive complexes. Note the ring-shaped magnetic expression of the Badwater Complex. Geophysical data from Ontario Geological Survey (1999, 2004). UTM co-ordinates in NAD83, Zone 16. Claim units as of December 15, 2020.

Summary

The potential for rocks associated with the Geon15 magmatic event in the Lake Nipigon region to host gold mineralization remains high and relatively untested. It is recommended that individuals focus exploration efforts toward rocks associated with the EBC and BIC as they remain ideal geological environments to host IOCG style mineralization. It is also recommended that individuals further investigate the magmatic-hydrothermal component of gold deposits associated with late-stage, magnetic, felsic intrusions described by Beakhouse (2007) as it may shed light on previously under-appreciated deposit models for many gold occurrences, thereby increasing the potential for significant discovery.

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HIGHLIGHTS

- **The Tontine Group copper, zinc, nickel, gold and silver occurrences are located in eastern Gzowski and western Kowkash townships**
- **This area has geology indicative of potential for both VMS zinc-copper and lode gold mineralization**
- **This area has seen limited historical exploration activity and is largely open for staking**

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Multi-Commodity Potential in Gzowski and Kowkash Townships

The Tontine Group of occurrences is located within an underexplored portion of the Onaman–Tashota greenstone belt that is prospective for volcanogenic massive sulphide (VMS) and lode gold mineralization. The group consists of 6 mineral occurrences of gold, silver, nickel, zinc and copper (Table 1; Ontario Geological Survey 2020a) straddling the boundary between Gzowski and Kowkash townships approximately 70 km north of Geraldton. At the time of writing the area remains open for claim registration.

Table 1. Mineral occurrences of the Tontine Group, data *from* Ontario Geological Survey 2020a).

MDI Identification Number	Occurrence Name	Primary Commodity	Secondary Commodity	Deposit Status
MDI42L06SW00014	McCann	Gold	Iron, Silver	Occurrence
MDI42L06SW00013	Tontine, 70-10	Nickel	Gold, Silver	Occurrence
MDI42L06SW00010	Tontine Silver 1	Silver	Copper	Discretionary Occurrence
MDI42L06SW00009	Tontine Silver 1	Silver	Copper	Discretionary Occurrence
MDI42L06SW00006	Tontine, 70-12	Copper, Silver	Gold	Discretionary Occurrence
MDI42L06SW00003	Tontine, 70-8	Zinc	Silver	Discretionary Occurrence

The Onaman–Tashota greenstone belt straddles the width of the eastern Wabigoon subprovince. It is mainly composed of Neoarchean metavolcanic rocks, including basalt, dacite and rhyolite that occur as flows, autobreccia and pyroclastic rocks (Stott et al. 2002). Older Mesoarchean metavolcanic rocks also occur near the western margin of the belt where it wraps around the Robinson pluton. The supracrustal rocks of the belt also include metasedimentary units that form the youngest surpracrustal assemblages and reflect uplift and erosion of the underlying volcanic and plutonic rocks (Stott et al. 2002).

The Tontine Group is primarily hosted within a subcircular unit of Neoarchean (2730–2759 Ma) intermediate metavolcanic rocks consisting of dacitic flows and tuff to lapilli tuff and pyroclastic breccia with a monzonite-monzodiorite-syenite core within the Willet assemblage (Figure 1). The Willet assemblage is the dominant assemblage within the Onaman–Tashota greenstone belt and is composed of massive to pillowed tholeiitic basalt with rare interbeds of dacitic tuff or resedimented tuff (Stott et al 1984, 1999, 2002). Rare-magnetite–chert

Paju, G.F. 2021. Multi-commodity potential in Gzowski and Kowkash townships; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2020-2021, p.24-28..

± sulphide iron formation occurs as magnetic high anomalies on aeromagnetic maps (McCannell 1952; Zurowski 1974; Burton 1990; Ontario Geological Survey 1999, 2003). Such iron formation horizons were noted in the logs of diamond-drill holes that were advanced by Tontine Mining Limited (Zurowski 1970a, 1970b).

Gold has been the primary exploration target in the Tontine Group area since it was first discovered in 1915 at the King Dodds occurrence near Howard Falls on the Kawashkagama River (MDI42L06SW00007; Hopkins 1916). The King Dodds occurrence is located approximately 10 km northeast of the Tontine Group (*see* Figure 1).

A diamond-drilling program was completed in the Tontine area in 1952. This program was completed by an unknown party and consisted of 2 holes (1180 feet), with no assays reported (assessment file 42L06SE0051, Unknown Author 1952). Tontine Mining Limited completed a 13 hole, 1588 m diamond-drilling program in 1970, with the deepest hole (DDH 70-6) extending 226 m and including an assay of 0.53 Ag/oz over 4.9 m (Zurowski 1970a, 1970b; Peterson 1970a, 1970b, 1970c). Several airborne and ground-based geophysical surveys have also been completed in the area by exploration companies and the Ontario Geological Survey (McCannell 1952; Zurowski 1974; Moffat 1976; Burton, 1990 and Ontario Geological Survey 1999).

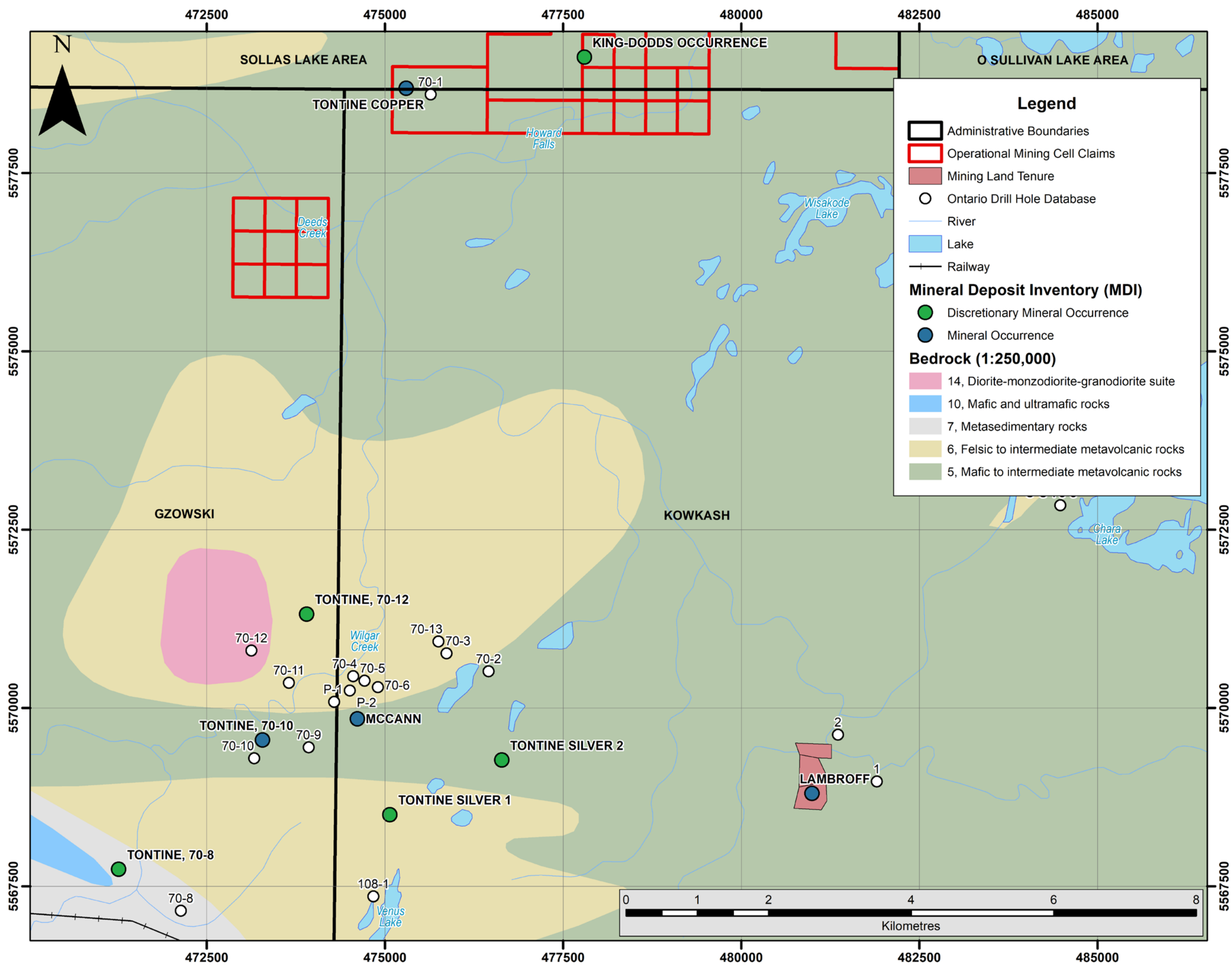

Figure 1. Geology and location of mineral occurrences and diamond-drill holes of the Tontine Group area in Gzowski and Kowkash townships. Geology data from Ontario Geological Survey (2011) and Stott et al (1999). Drill-hole data from Ontario Geological Survey 2020b. Universal Transverse Mercator (UTM) co-ordinates in North American Datum (NAD83), Zone 16. Claim units current as of October 14, 2020.

The 1970 diamond-drilling program intersected various cherty and graphitic metasedimentary rock horizons, oxide ± sulphide iron formations and tuff horizons. These stratigraphic intervals were sulphide mineralized, with sulphide content ranging up to 40 to 100%. Mineralization ranged from disseminated to massive and included pyrrhotite and pyrite, with local instances of 40 to 80% disseminated to massive marcasite (DDH 70-3 and 70-6; Zurowski 1970a, 1970b). The sulphide mineralized horizons are described as being interbedded with porphyry intrusions, presumed pillowed mafic volcanic flows and poorly sorted/foliated dacitic pyroclastic breccia that is generally massive in appearance. One drill hole (DDH 70-2) encountered a 300 foot-thick zone of dacitic breccia containing disseminated sulphide throughout, with the main sulphide mineralization occurring in intervals of 40 to 60% pyrrhotite and pyrite contained in chert bands ranging from roughly 15 to 60 cm thick (Zurowski 1970a). Carbonate, chlorite, and silica alteration was reported in various lithologies; particularly within the dacite breccia, iron formation and metasedimentary rock/tuff horizons, possibly indicative of the presence of a nearby VMS feeder zone.

The 1970s drill program appears to have been targeting small magnetic high anomalies (Figures 2 and 3). The program found elevated levels of silver (0.56 oz/ton), copper (0.4%), nickel (0.03%), zinc (0.4%) and gold (0.005 oz/ton) (Peterson 1970a, 1970b, 1970c; Zurowski 1970a, 1970b).

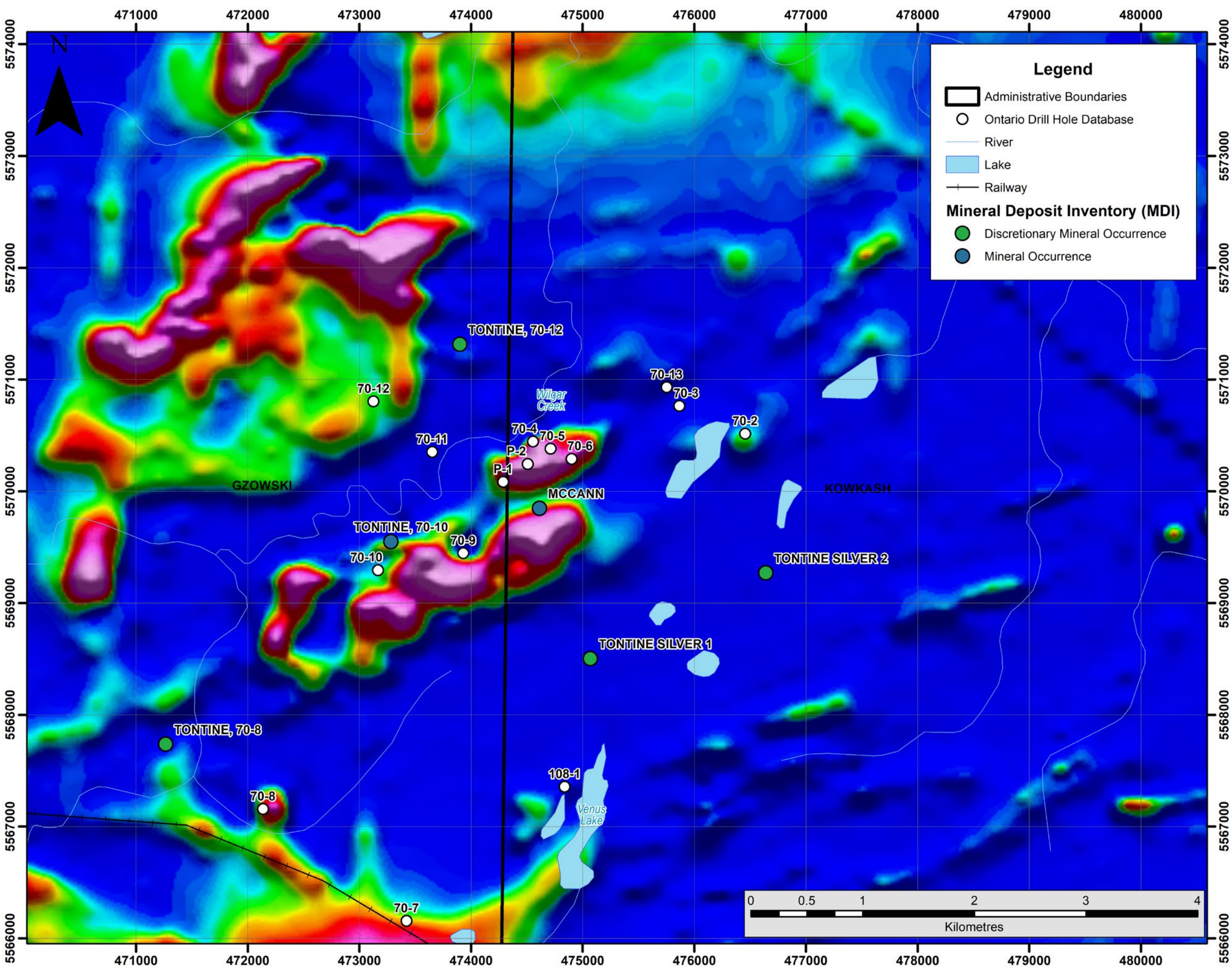

Figure 2. Map of the Tontine Group overlain by the residual magnetic image shows magnetic anomalies of the western Kowkash Township. Geophysical data *from* Ontario Geological Survey (1999, 2003). Drill-hole data *from* Ontario Geological Survey 2020b. Universal Transverse Mercator (UTM) co-ordinates in North American Datum (NAD83), Zone 16. Claim units current as of October 14, 2020.

The Tontine Group area has geological characteristics that suggest that it has potential for the discovery of VMS and gold mineralization. These include:

- anomalous base and precious metal values that were obtained from historical exploration programs;
- physical and geochemical trap lithologies (e.g., chert and iron formation horizons), and;
- hydrothermal alteration (carbonatization, chloritization and silicification).

The area has seen limited exploration since the 1970s, with none utilizing modern gold or VMS targeting methods. Detailed prospecting and till/soil sampling in the vicinity of known occurrences and host lithology extensions could aid in delineating mineralized areas; including barren iron sulphides and alteration halos not previously discovered in outcrop which may vector to further mineralization. Conducting such work in conjunction with modern geochemical and geophysical (e.g., magnetic and electromagnetic) surveys will aid in refining prospective lithologies and prioritizing explorations targets.

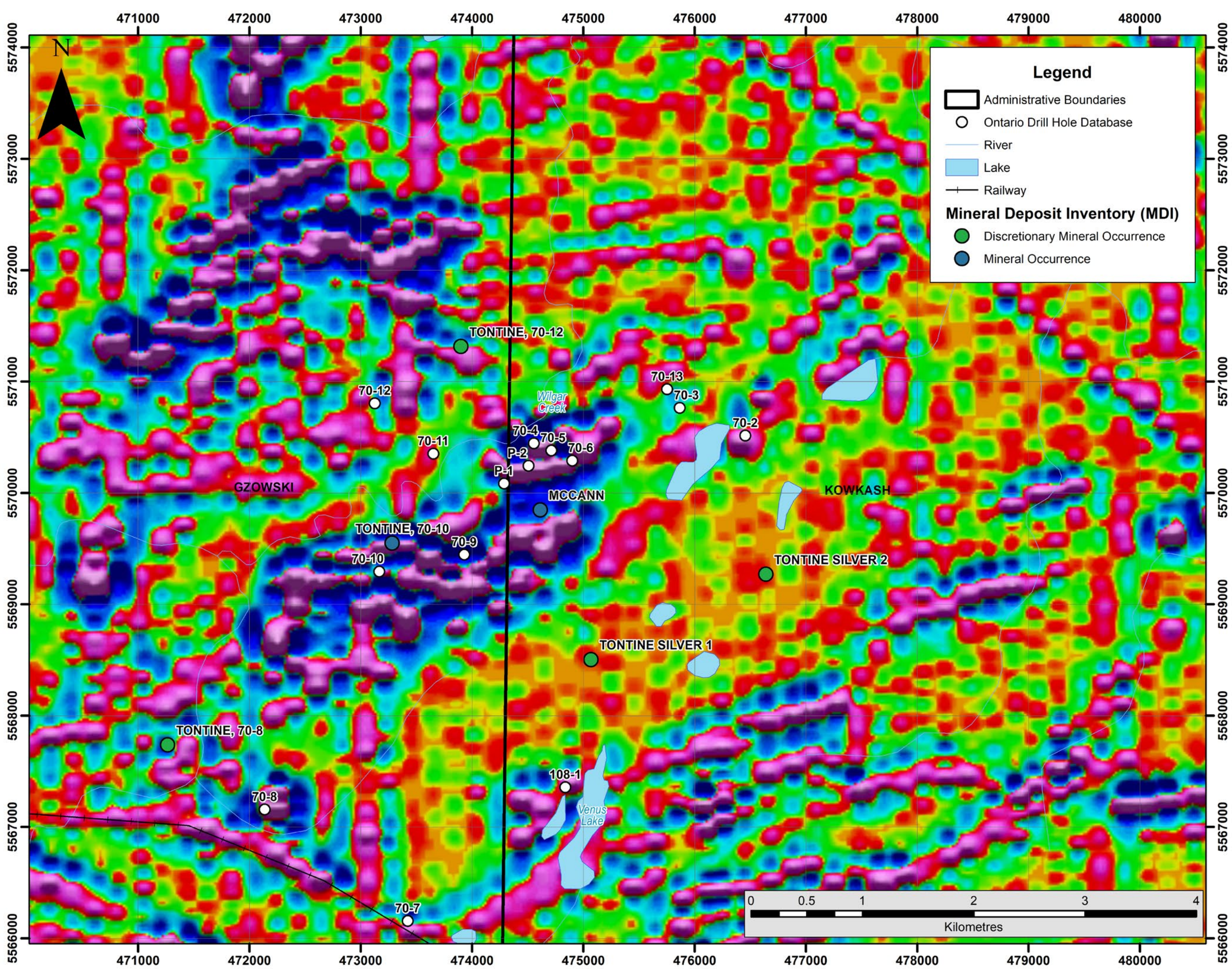

Figure 3. Map of the Tontine Group overlain by the second vertical derivative magnetic image shows magnetic anomalies of the western Kowkash Township. Geophysical data *from* Ontario Geological Survey (1999, 2003). Drill-hole data *from* Ontario Geological Survey 2020b. Universal Transverse Mercator (UTM) co-ordinates in North American Datum (NAD83), Zone 16. Claim units current as of October 14, 2020.

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HIGHLIGHTS

- **Copper occurrences located along a regional-scale, northwest-trending fault (Little Joe Lake fault, Vein Lake area) are open for staking, as of December 14, 2020**
- **Reported historical copper assays range from 0.28% Cu over 4.5 m up to 5.02% Cu over 5 m (including 9.35% Cu over 1.7 m)**
- **Copper mineralization along the Little Joe Lake fault appears to be similar to the Far Lake copper occurrences (west of Thunder Bay) recently discovered by Benton Resources Inc. and White Metal Resources Corp.**

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Copper Potential Along the Little Joe Lake Fault

Copper prices are projected to increase as the market for electric vehicles (EVs) is on a rapid upward trend. According to Wood MacKenzie (2019), copper is a cornerstone of the EV revolution. Electric vehicles can use up to 3.5 times as much copper when compared to an internal combustion engine passenger car. The switch to electric vehicles will have important implications on the price and demand for copper.

A base-case scenario by the International Energy Agency, suggests the use of electric vehicles on a global scale is expected to rise from 4 million vehicles in 2018 to 120 million by 2030; however, depending on environmental policies the estimate could range between 57 and 300 million by 2030 (Latulippe and Mo 2019).

The governments of Ontario and Canada recently announced a combined $590 million investment for Ford Motor Company's $1.8 million retooling of its Oakville assembly plant to start rolling electric vehicles off the line by 2025 (CBC 2020).

The Baarts–Donaldson copper occurrence is located along a regional-scale, northwest-trending fault referred to as the Little Joe Lake fault (Figure 1). Copper mineralization has been traced along the Little Joe Lake fault (LJLF) for approximately 2.5 km (McKay 1994). Hawkins (1971) reported channel and chip sample assay results from the Baarts–Donaldson copper showing ranging from 0.28% Cu over 4.5 m up to 5.02% Cu over 5 m (including 9.35% Cu over 1.7 m). The main copper showing on the Baarts property is located approximately 32 km west-southwest of Manitouwadge and 6 km southeast of Vein Lake and is open for staking as of October 9, 2020 (*see* Figure 1).

The exploration history of copper occurrences in the Vein Lake area dates to 1955, when prospectors R. Barker and W. Dawidowich completed surface mapping and trenching at a copper showing, now referred to as the Baarts–Donaldson copper occurrence. The work reportedly outlined a mineralized zone 300 feet long by 20 feet wide that averaged 1% Cu (Mckay 1994). In 1955, Lexinden Gold Mines Ltd. (Knight 1955) carried out geology and ground magnetic surveys south of the Baarts–Donaldson copper occurrence, reporting sulphides, at locations now referred to as the Big Joe Creek and Lloyd Davis discretionary occurrences; however, no assay results were reported. Since then, sporadic exploration has been carried out by prospectors and a few exploration companies; however, most assessment reports do not provide assay data, geological information or updated geophysical information. A detailed history of exploration at the Baarts–Donaldson occurrence is available in volume 2 (p.261-271) of Mckay's report (McKay 1994).

Campbell, D.A. 2021. Copper potential along the Little Joe Lake fault; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2020-2021, p.29-34.

Access to the Baar–Donaldson copper showing near Little Joe Lake is via a network of forestry roads, north and west of Manitouwadge (*see* Figure 1).

The area was mapped by Milne (1968) and by Coates (1967,1970). The Baarts–Donaldson copper occurrence is situated within the Wawa Subprovince. The dominant rock types in the Vein Lake area are Archean age granitic-gneisses with lenses of north-northeast trending metavolcanic rocks, intruded by the Proterozoic age Killala Lake alkalic complex (syenites and gabbros) and diabase dikes. There are 3 major regional fault trends in the area; i) northwesterly, ii) northeasterly and iii) north to N15E (Coates 1970). The Baarts–Donaldson copper occurrence is located along the northwest-striking Little Joe Lake fault, which is marked by a prominent magnetic low extending for approximately 34 km, as shown on Figure 3.

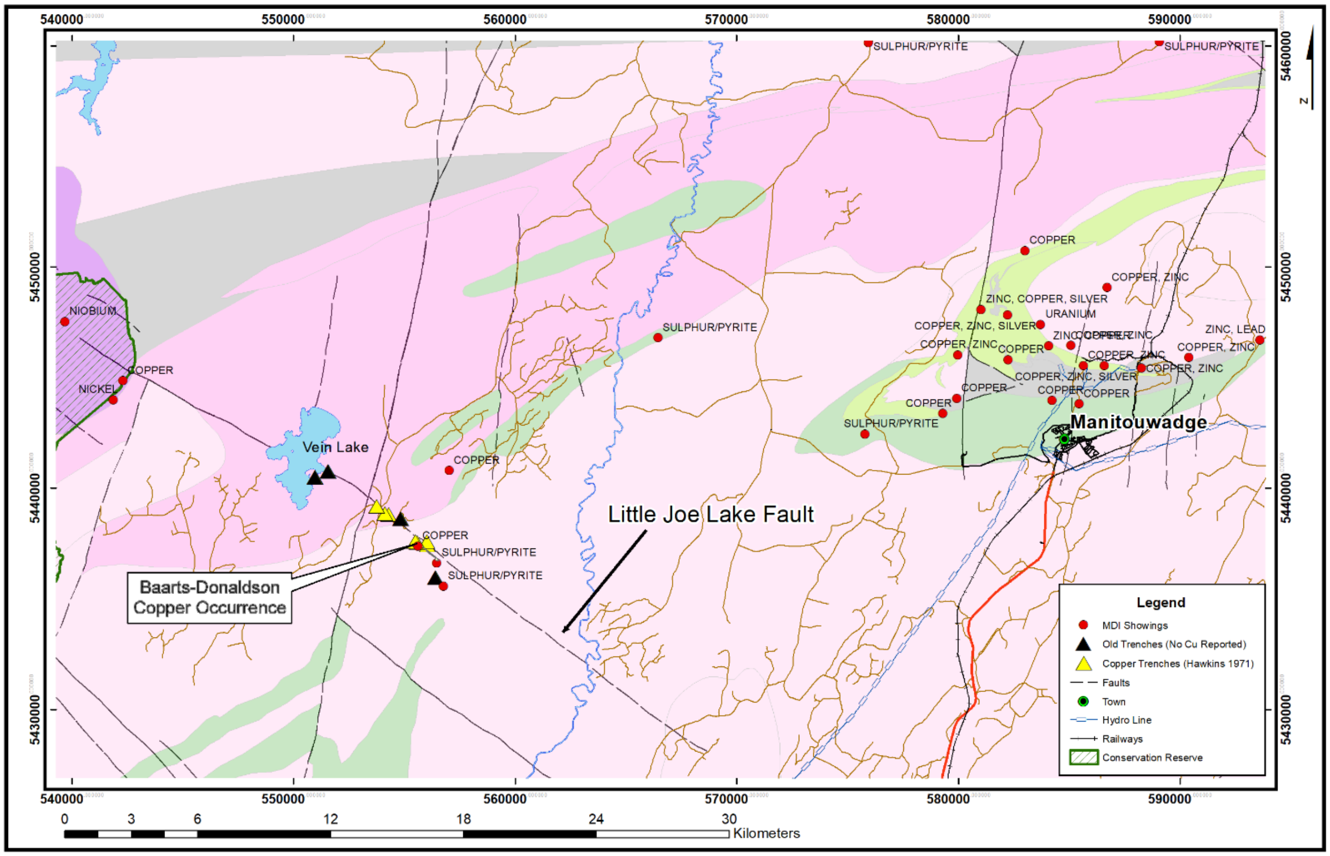

Figure 1. Map illustrating location of the of the Little Joe Lake fault (outlined in black dashes), copper showings (yellow triangles) and old trenches (black triangles). Access is via Highway 614 (red line) to Manitouwadge and continuing onto forestry roads north and west of Manitouwadge (brown lines) to access the Little Joe Lake fault and trenches. Regional geological map (modified from Ontario Geological Survey 2011) and mineral occurrences and showings from assessment files and the Mineral Deposit Inventory (Ontario Geological Survey 2020).

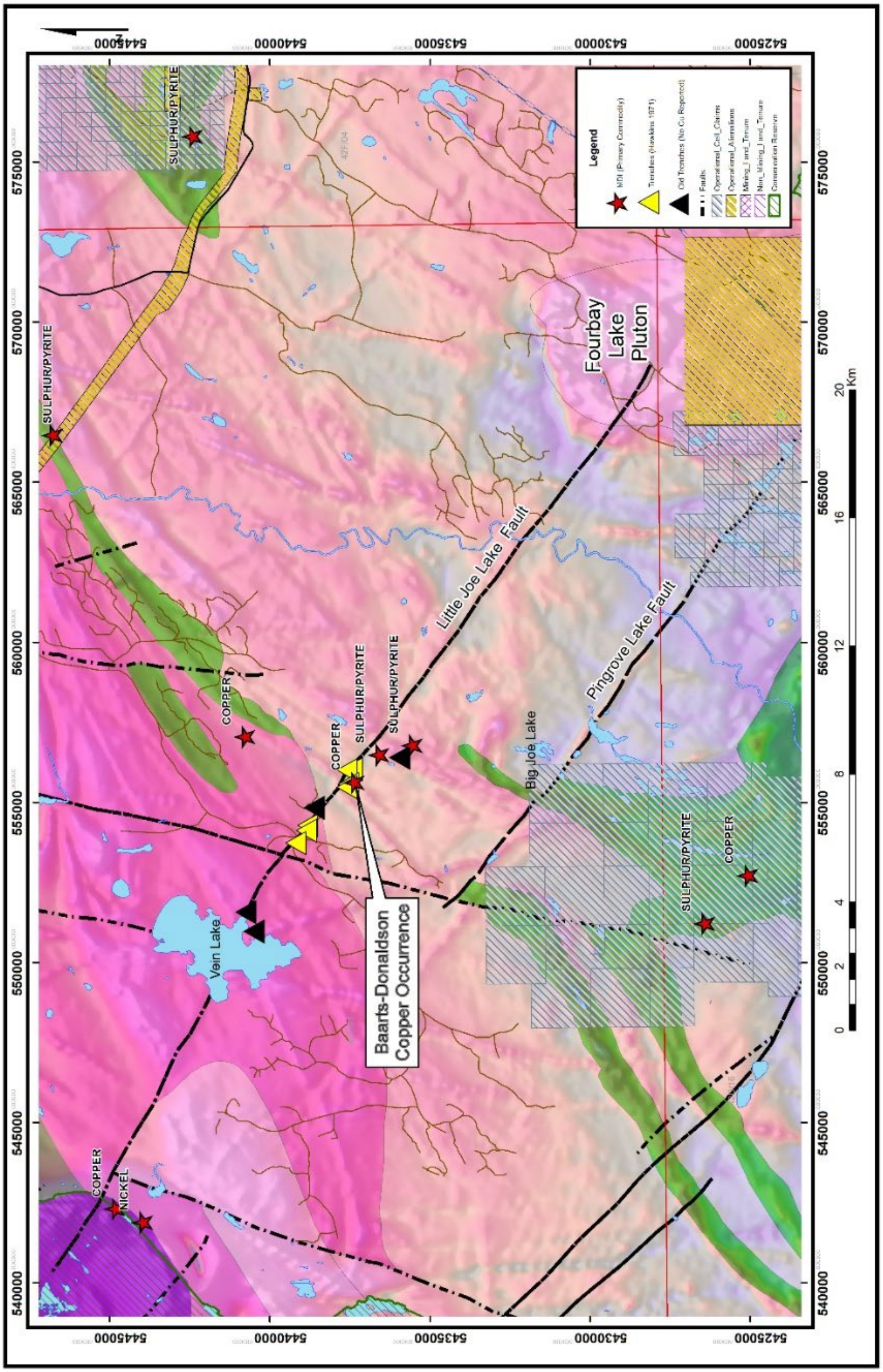

Figure 2. Regional geological map (*modified from* Ontario Geological Survey 2011) superimposed on the residual total magnetic field (*from* Ontario Geological Survey 1999, 2002) showing the location of the Baarts–Donaldson occurrence along the Little Joe Lake fault and the location of staked claims (grey outlines) as of October 9, 2020.

In 1991, McKay (Schneiders, Smyk and McKay 1992) examined, located and collected samples from 5 trenches at the Baarts property, providing the following geological information and assay results (Table 1):

> The occurrence is hosted primarily in pink, coarse-grained granite and granitic gneiss. Local lenses and pods of migmatized, mafic metavolcanic rocks and quartz-feldspar pegmatite are also present. The occurrence is spatially associated with the northwest-trending Little Joe Lake fault. Northeast-trending bands of amphibolitized mafic metavolcanic gneisses occur southeast and northwest of the occurrence.
>
> The occurrence consists primarily of erratically distributed sulphides and associated weathering products hosted in narrow zones of altered, sheared and brecciated granite and granitic gneiss. The location of the mineralization appears to be controlled by the Little Joe Lake fault and/or related parallel faults. All of the copper mineralization exposed in the trenches was confined within, or adjacent to, these faults. The mineralized zones examined varied in width from approximately l m to 4 m. In a 3 m high cliff exposure located approximately 250 m west of Little Joe Lake, the mineralized zone dips steeply southwest and widens with depth. The sulphide mineralization consists primarily of fine- to medium-grained, disseminated grains of pyrite and coarser-grained anhedra and blebs of chalcopyrite. The sulphides tend to be concentrated in zones rich in quartz and may locally constitute up to 5 % of the host. Azurite and malachite staining are common within the mineralized zones. Veinlets of chalcocite and covellite are reported to occur within some of the mineralized zones (Hawkins 1971) but none were observed during the present examination. The host granite and granitic gneiss are locally strongly silicified and hematitized. Several narrow veinlets of fine-grained, foliation-parallel specular hematite occur adjacent to the main mineralized zone exposed just west of Little Joe Lake.

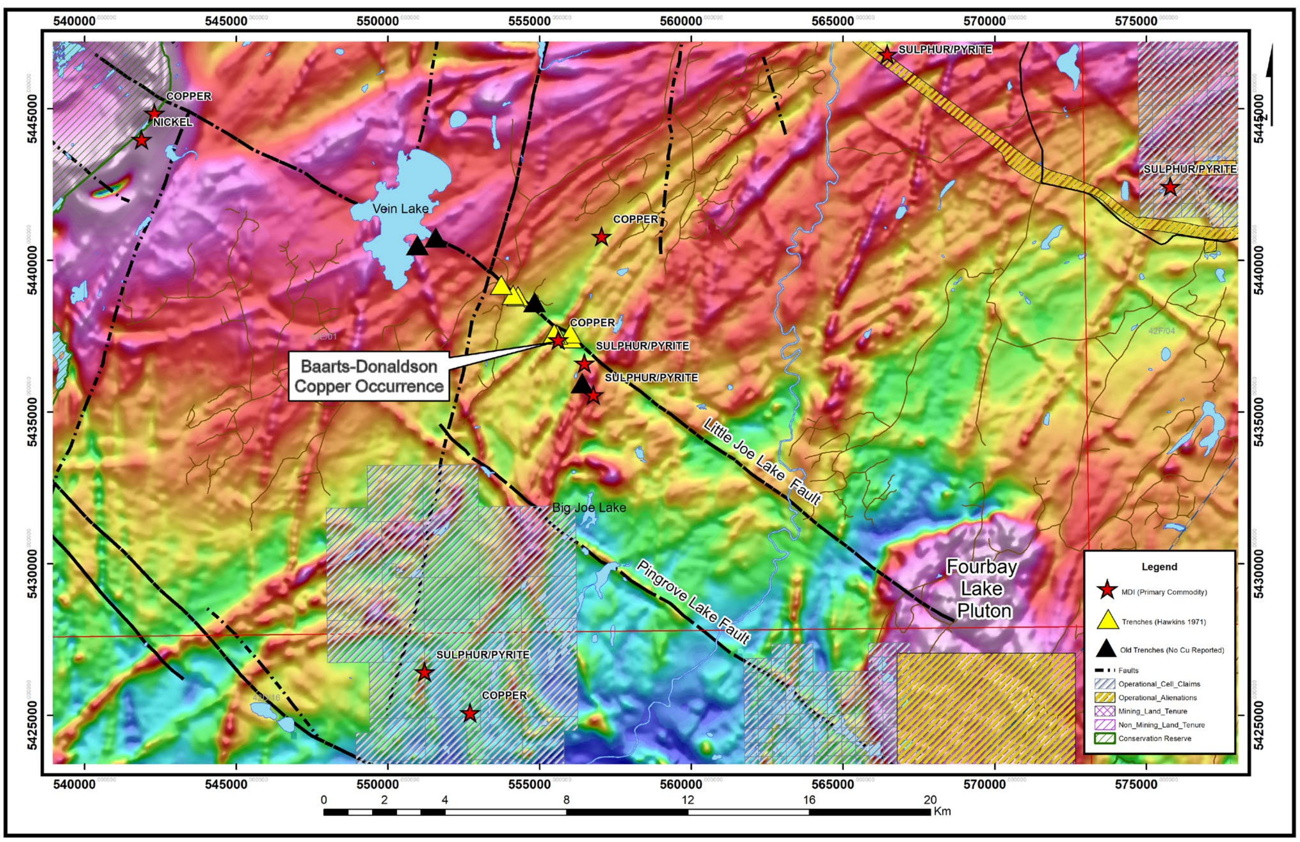

Figure 3. Regional residual total magnetic map (*modified from* Ontario Geological Survey 1999, 2002)) showing prominent magnetic low marking the Little Joe Lake fault, location of Baarts–Donaldson occurrence and the location of staked claims (grey outlines) as of October 9, 2020.

Table 1. Assay results from grab samples taken by McKay in 1991 (*see also* Schneiders, Smyk and McKay 1992, Table 7.13).

Sample	Gold oz/t	Silver oz/t	Copper (%)	Zinc (%)	Sample Description (grab)
91DBM-132	trace	nil	0.3780	0.0008	rusty, brecciated, vuggy, hematitized granite gneiss, <1% fine- to medium grained chalcopyrite as disseminated grains, rare bornite, trench No.1, approximately 475 m east of Little Joe Lake
91DBM-133	trace	nil	0.8140	0.0034	gray-white composite quartz vein, approximately 15% angular, granitic xenoliths, 2% to 3% chalcopyrite as irregular blebs up to 3 mm in size, trench No.2, approximately 250 m west of Little Joe Lake
91DBM-134	0.003	trace	3.4200	0.0046	rusty, purple, hematitized and brecciated granite gneiss, abundant malachite, trace sulphides, pit No.2
91DBM-135	trace	nil	0.0240	0.0018	pink-brown, massive, unaltered granite gneiss, trace medium-grained pyrite, host to mineralized zone, pit No.2
91DBM-136	nil	nil	0.3110	0.0091	rusty, weakly foliated granite gneiss, stained with malachite, proximal to southwest contact of mineralized zone, pit No.2
91DBM-137	nil	nil	0.5690	0.0010	rusty, purple, hematitized, silicified, brecciated granite gneiss, trace chalcopyrite, malachite stained, pit No.3 (grab), 60 m east of pit No.2
91DBM-139	nil	nil	0.3580	0.0014	altered, brecciated granite gneiss similar to 91DBM-137, pit No.3
91DBM-140	nil	nil	0.0070	0.0016	massive, pink, coarse-grained granitic gneiss, host to mineralized zone, up to 20% specular hematite in narrow subparallel veinlets up to 3 cm wide, pit No.4, 25 m west of pit No.1
91DBM-142	trace	trace	0.3960	0.0026	mottled, purple, hematitized, silicified, vuggy, brecciated granite gneiss, minor malachite, no visible sulphides, pit No.5, approximately 1 km west of pit No.2
91DBM-144	nil	nil	0.4320	0.0026	altered, brecciated granite gneiss similar to 91DBM-142, cut by narrow veins containing irregular blebs of chalcopyrite up to 5 mm in size, pit No.5

In the early 1970's, Hawkins (1971) made 2 property visits to the Baarts property and completed a geological report on "The Economical Potential of the L.M.M. Baarts Property." Hawkins (1971) reported the following assay results:

- **Trench 1:** channel sample; 0.45% Cu over 26 feet (ranging from 0.14% to 1.08% Cu). Channel Sample submitted by Noranda Mines Ltd., to the Ontario Department of Mines Laboratories (Certificate of Analysis C11036, September 2, 1964).
- **Trench 2:** channel sample; 0.28% Cu over 15 feet.
  Technical Services Laboratories, Toronto (Certificate of Analysis Report C4101-4, October 14, 1964).
- **Trench 4:** channel sample; 0.54% over 18 feet.
  Technical Services Laboratories, Toronto (Certificate of Analysis Report C4101-4, October 14, 1964).
- **Trench 4:** Trench 4 was deepened in September 1970, chip samples; average 5.02% Cu, 0.25% Zn, 0.30 oz/t Ag over 16.5 feet, included the following:

  3.69 % Cu, 0.41% Zn, 0.08 oz/t Ag over 8.0 feet;
  0.64 % Cu, 0.11% Zn, 0.10 oz/t Ag over 3.0 feet;
  9.35 % Cu, 0.11% Zn, 0.73 oz/t Ag over 5.5 feet.

Samples submitted to GECO Mines Limited, assay sheet with GECO letterhead, October 2, 1970.

Based on the trenching and assay results of copper mineralization in brecciated and sheared sections along the Little Joe Lake fault, Hawkins (1971) recommended further exploration, including induced polarization, deep electromagnetic surveys and diamond drilling. Hawkins (1971) reported that the copper mineralization at the Baarts property "resembles in a general way the breccia zone at the Tribag Mine, 50 miles north of Sault Ste. Marie."

Copper mineralization along the Little Joe Lake fault appears to be similar to the Far Lake copper occurrences, recently discovered west of Thunder Bay by Benton Resources Inc. and White Metal Resources Corp (Puumala 2020). The Far Lake copper occurrences are associated with a northwest trending, brecciated and silicified structure that bisects granitic rocks within the Quetico Subprovince.

Considering increased demand for copper, increased commodity prices and increased metal recovery methods, as well as new advances in geophysics, geological concepts and geochemical analysis, the copper showings along Little Joe Lake fault warrant further exploration.

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HIGHLIGHTS

- **Southwestern Batchawana greenstone belt represents a relatively underexplored Archean terrane that hosts multiple gold occurrences**
- **Positive results from recent exploration warrant further investigation of the region's gold potential**

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Gold Potential in the Southwestern Batchawana Greenstone Belt

Various gold occurrences are documented in the southwestern Batchawana greenstone belt (Table 1). The belt is located approximately 100 km south of the Michipicoten greenstone belt, which hosts multiple operating orogenic gold mines.

The southwestern Batchawana greenstone belt hosts multiple historic copper ± gold mines (i.e., Coppercorp Mine, Tribag Mine–Breton Breccia, and Mamainse Mine; Figure 1). It comprises Archean mafic to intermediate metavolcanic rocks and metasedimentary rocks, that are intruded by felsic metavolcanic rocks. The westernmost portion of the map area is overlain by basalts and intrusive rocks of the Proterozoic Keweenawan Supergroup (Giblin and Armhurst 1973). Lithologies of the area are crosscut by multiple east-northeast- and north-northwest-trending faults and shear zones. Although multiple gold occurrences have been documented within the southwestern Batchawana greenstone belt (*see* Figure 1), and it comprises lithologies and structures that are conducive to hosting various types of gold mineralization, it remains relatively underexplored for gold.

Recent gold exploration

Recent exploration conducted at the Wish Ore and Glenrock and Doyle properties provides evidence for gold mineralizing systems within the greenstone belt.

The Wish Ore property (*see* Figure 1) is underlain by sequences of tholeiitic metavolcanic flows, which are increasingly intercalated with metasedimentary rocks, including iron formations, and felsic tuffs towards the east (Tremblay 2015). Gold mineralization is associated with volcanic rocks with quartz veining and carbonate alteration, low concentrations of sulphides and chalcopyrite mineralization, and northwest-trending shear zones that intersect the east-northeast-trending Carp River Fault (Golden Goliath Resources 2019a). Gold values of up to 4.28 g/t gold over 3 m, including 9.05 g/t gold over 1.0 m, were identified based on channel sampling on the property (Golden Goliath Resources 2019b).

The Glenrock property (*see* Figure 1) is associated with sheared mafic metavolcanic rocks, as well as significant patches of sulphide mineralization and carbonate alteration (MDI41N02SE00004; Ontario Geological Survey 2020). Recent surface rock sampling at the property reported values up to 3.29 g/t Au, and results of 15 soil samples delineated an approximately northwest-trending zone of elevated values up to 1.72 g/t Au, averaging 0.18 g/t Au. Analysis of the property's

Zammit, K. 2021. Gold potential in the southwestern Batchawana greenstone belt; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2020-2021, p.35-38.

historical drill core from the Sault Ste. Marie District drill core library (*see* Figure 1) revealed up to 0.99 g/t Au over 0.8 m (Stone Gold Inc. 2020).

The Doyle property is located in the northeastern Batchawana greenstone belt, which was previously recommended for gold exploration by the Ontario Geological Survey (Pace 2016). The property is underlain by felsic volcanic and volcaniclastic sedimentary rocks that have shown widespread zinc and gold mineralization through previous drilling and trenching (Talisker Gold Corp. 2018). Though it is not in the immediate vicinity of the area considered for this recommendation, the Doyle property comprises lithologies and structures that are conducive to hosting gold mineralization, and provides further evidence to support the presence of gold mineralizing systems in the Batchawana greenstone belt.

Recommendation

Based on multiple recorded historic gold occurrences, and positive results from recent exploration work conducted in the Batchawana greenstone belt, it is recommended that further investigation into the belt's gold potential be considered.

Table 1. Summary of recorded gold occurrences in the southwestern Batchawana greenstone belt (Ontario Geological Survey 2020). Assessment files can be searched for and retrieved using the Ontario Geological Survey online data warehouse, *GeologyOntario* (www.ontario.ca/geology), or by contacting the Sault Ste. Marie District Geologist's office.

Township	Easting	Northing	Name	Primary (P) or secondary (S) occurrence	Mineralization classification	Number of assessment reports on file
Davieux (A.C.R)	713863	5222155	Mine Pond, Hammar Bridge	P	Hydrothermal	4
Olsen	704229	5220648	McCollough Lake	P	Hydrothermal	1
Olsen	709179	5220944	South Paquette	P	Hydrothermal	3
Olsen	701819	5218246	McGovern Lake	P	Hydrothermal	2
Olsen	703770	5218768	McGovern Lake East	S	Hydrothermal	1
Olsen	703297	5217722	Minnex 52-53	P	Lode	4
Palmer	683886	5209329	Glenrock	P	Lode/Hydrothermal	15
Palmer	684680	5206503	Palmer Gold	P	Lode/Hydrothermal	7
Palmer	686478	5210035	STP-10	P	Lode/Vein (Polymetallic)	3
Imer	686062	5211804	Palmer Breccia Zone	S	Hydrothermal	8
Wishart	693878	5209818	Wish Ore	P	Lode	1
	693888	5209829				

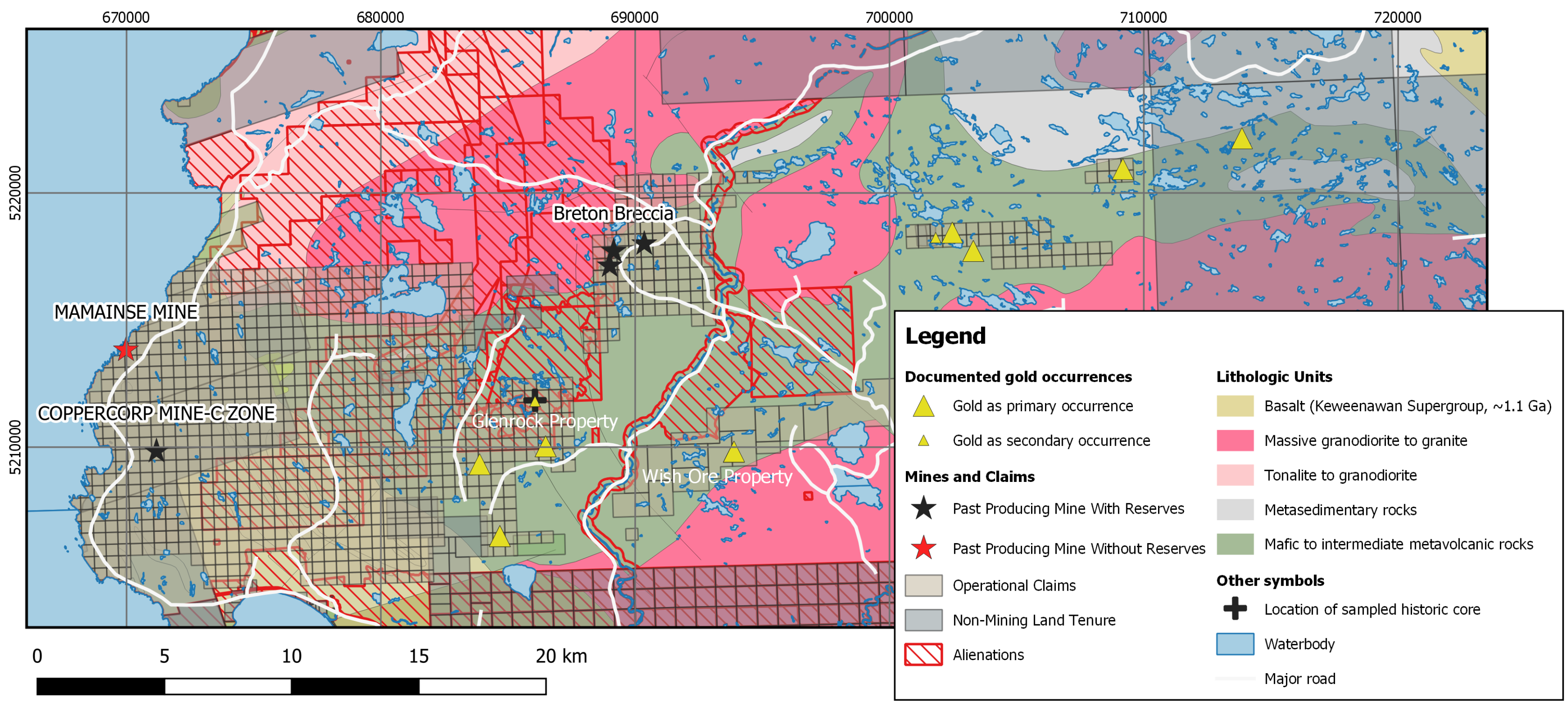

Figure 1. Simplified geological map showing the locations of documented gold occurrences in the southwestern Batchawana greenstone belt, as well as operational claims, mining alienations and historic mines. Co-ordinates are provided in UTM Zone 16N, NAD83. Data *compiled from* the Mineral Deposit Inventory database (Ontario Geological Survey 2020).

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HIGHLIGHTS

- **Maps showing gold occurrences in the Timmins District**
- **Maps reveal possible gold mineralization trends that mandate further investigation**

Looking Around for Gold

The Timmins District is host to world-class gold deposits. The names of Hollinger Mine, Dome Mine and McIntyre Mine call on dreams of wealth and prosperity. Nowadays, gold prices hover around the C$2500.00 per ounce (Kitco 2020). Gold exploration renewed vigor in the District. Where would you go? It is with this perspective that the following gold occurrence maps were created for the southern part of the Timmins District.

The map uses the Mineral Deposit Inventory for the baseline (MDI; Ontario Geological Survey 2020) and the bedrock geology for the background (Ontario Geological Survey 2011). Each point plotted is a mineral occurrence that is documented in the MDI, with a status ranging from occurrence to past-producing mine. All points have gold as either primary or secondary in the commodity declaration. It is up to the reader to further the research about the point and what triggered its notation (i.e., What is the context of the occurrence? What is the grade returned from the assay? Is the information reliable? Is it a volcanogenic massive sulphide deposit? What other commodities are present?). The use of the OGSEarth MDI layer on Google Earth™ or the Mineral Occurrences layer under Geology on the Mining Lands Administration System (MLAS) is recommended for that purpose.

Each point represented on the main map has approximately a 1 km radius. The MDI points are created when a commodity reaches a threshold amount in a location. In the case of gold, the threshold is 0.5 g/t. The minimum distance between MDI points is ~200 m. Points that are close together are potential prospects.

It is evident that 1 km radius points will overlap in the results. Some trends are apparent in that context; some in need of further work for confirmation (e.g., Dargavel Township, Carscallen Township, located to the north and southwest in the centre insert respectively, Figures 1 and 3). In Chester Township (located to the southeast in the southern insert, Figures 1 and 4), the points are in a cluster; the construction of Côté Lake Mine almost becomes self-evident.

These maps give insight to where to look for gold. Should that mean that all points on the map will lead to a gold deposit? No. However, it will increase your likelihood of finding a gold deposit.

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Bousquet, P. 2021. Looking around for gold; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2020-2021, p.39-44.

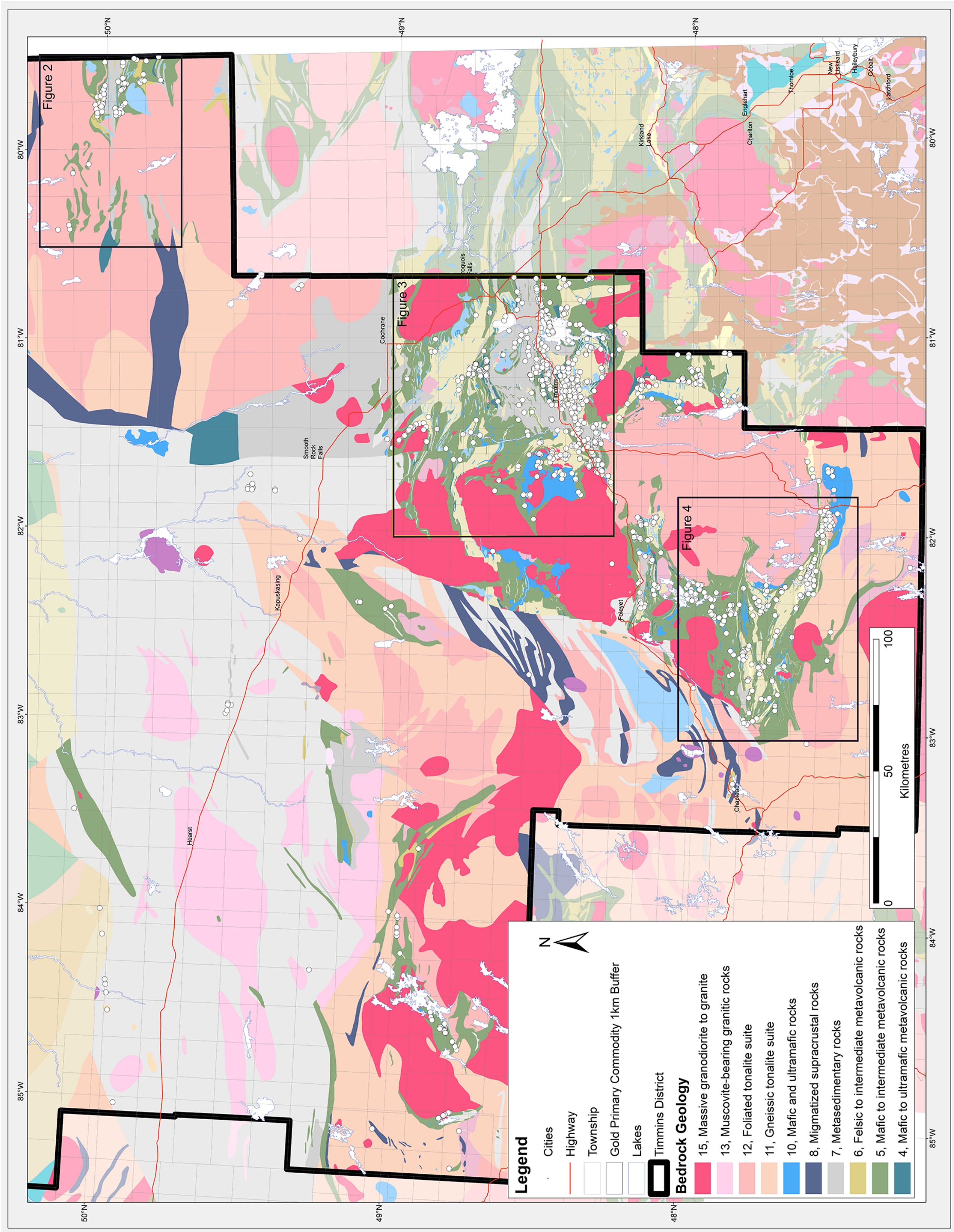

Figure 1. Bedrock geology map of the southern section of the Timmins District showing gold occurrences (white dots) *(modified from* Ontario Geological Survey 2011, 2020).

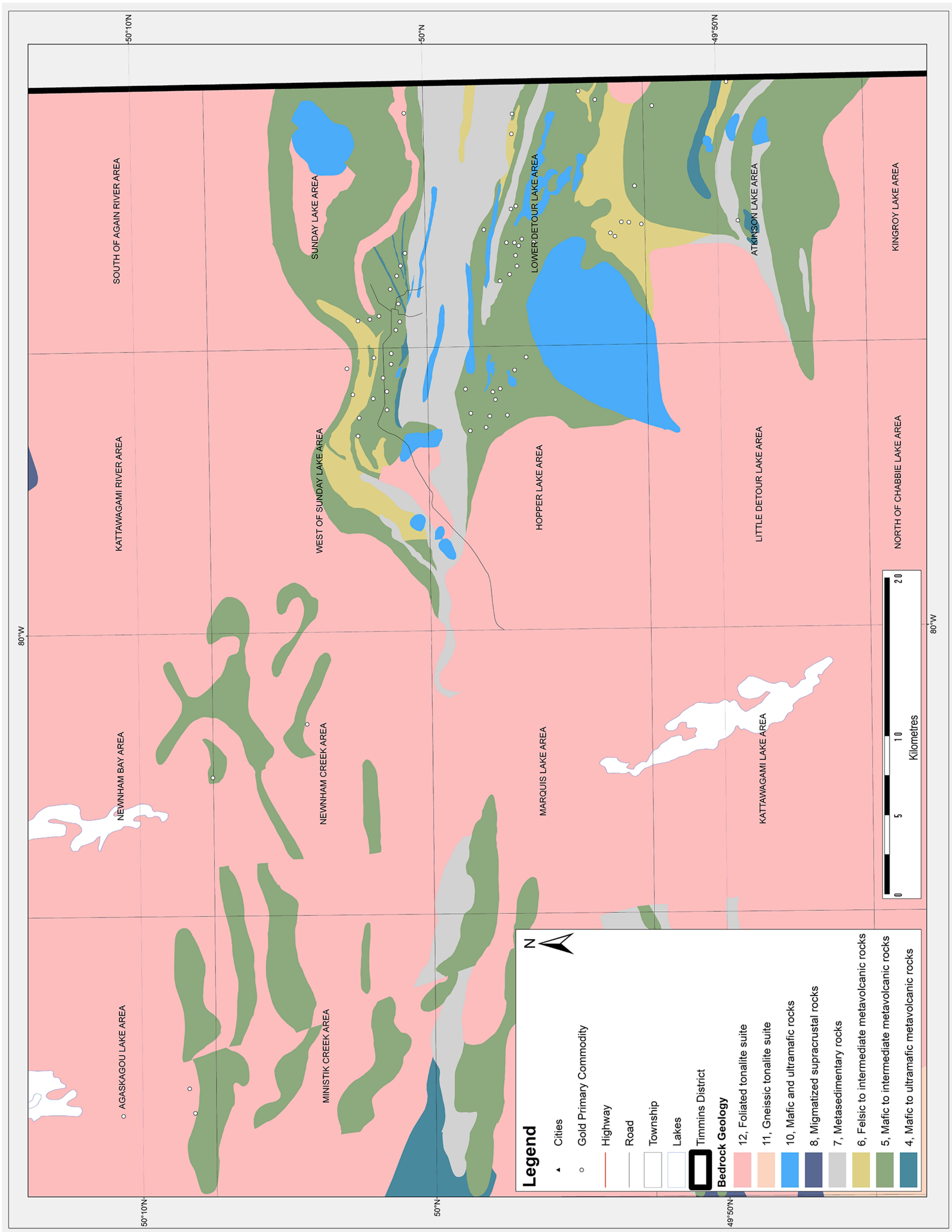

Figure 2. Bedrock geology map of the Detour Lake Area (*see* location of insert on main map of the Timmins District in Figure 1) with gold occurrences (white dots) (*modified from* Ontario Geological Survey 2011, 2020 data).

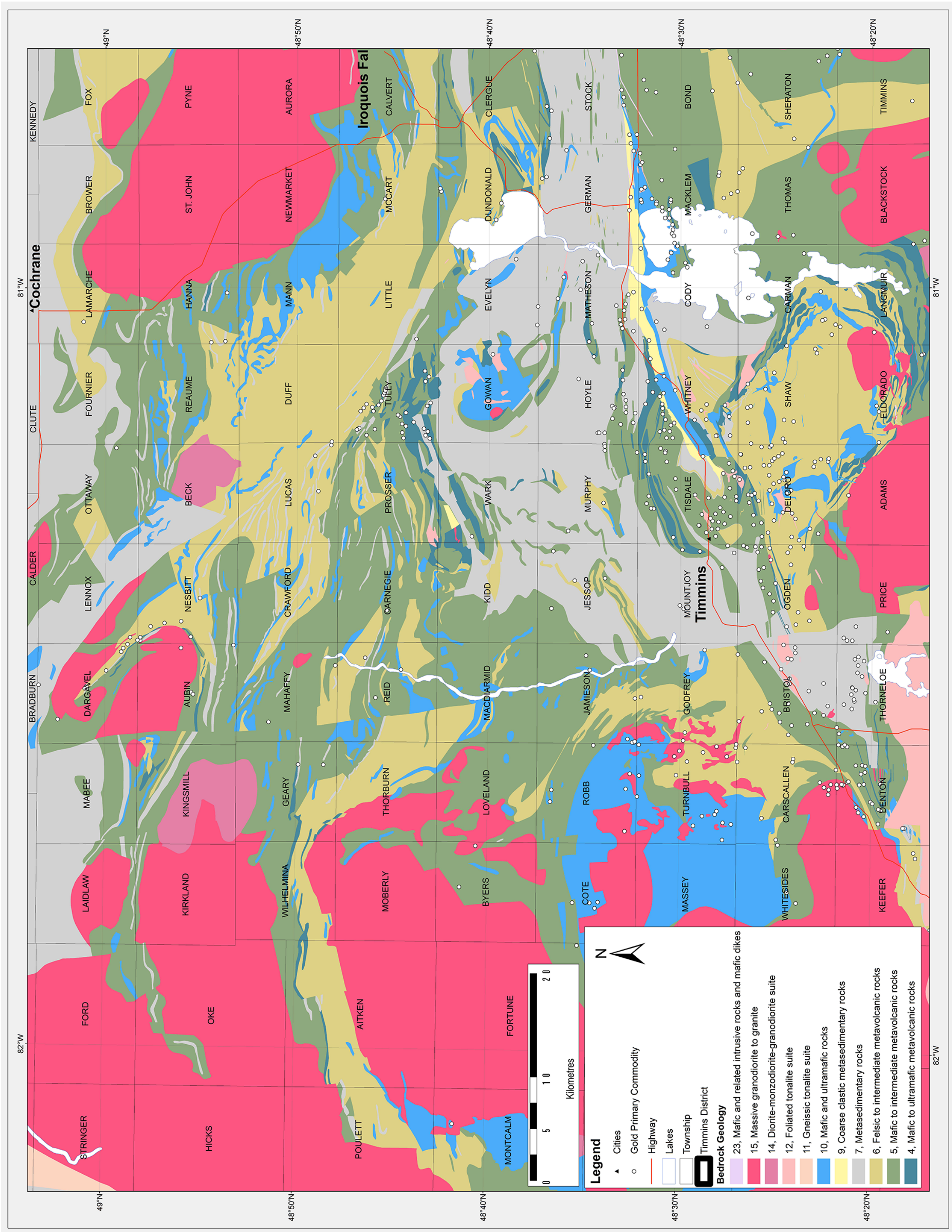

Figure 3. Bedrock geology map of the Timmins area (*see* location of insert on main map of the Timmins District in Figure 1) with gold occurrences (white dots) (*modified from* Ontario Geological Survey 2011, 2020 data).

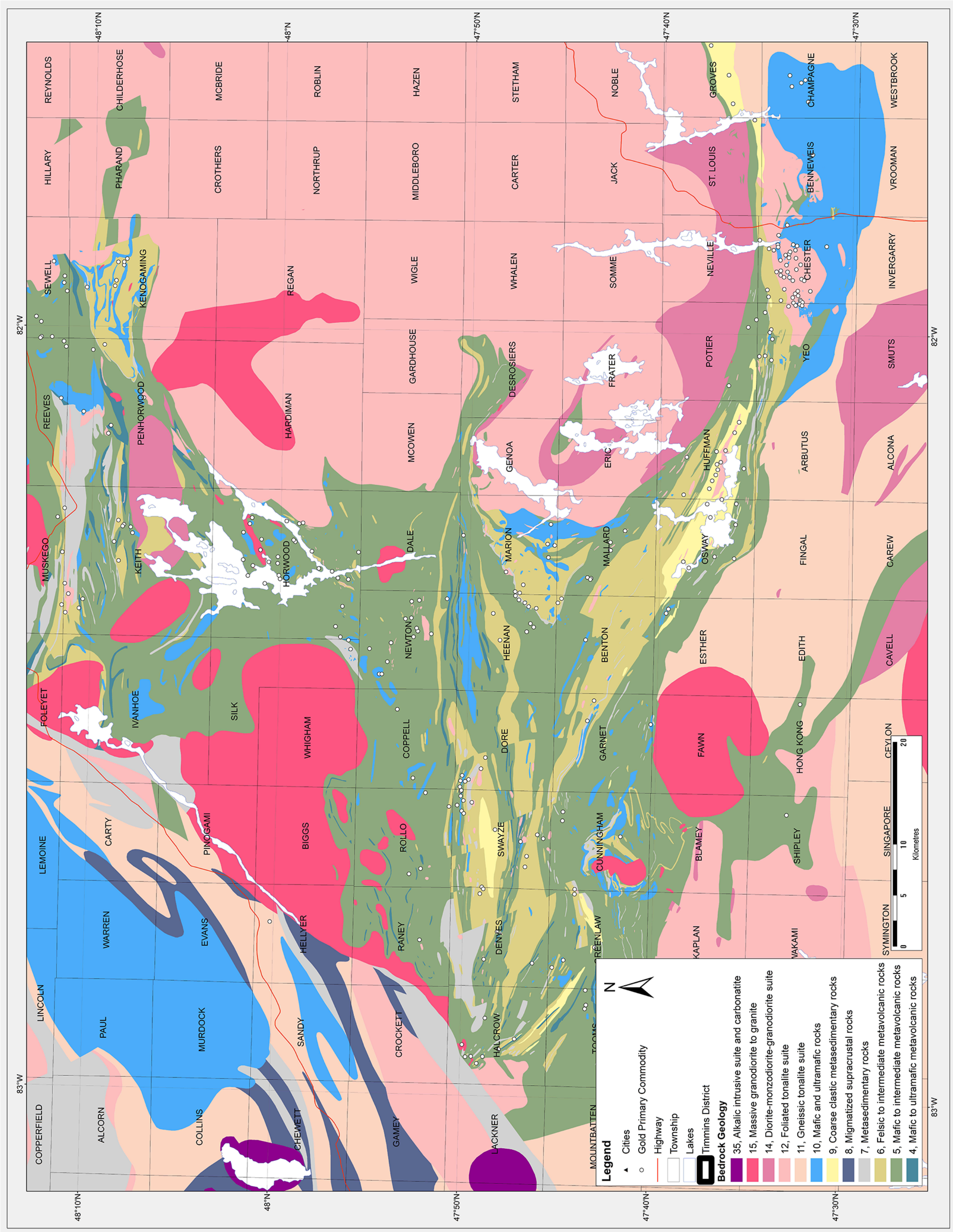

Figure 4. Bedrock geology map of the Swayze area (*see* location of insert on main map of the Timmins District in Figure 1) with gold occurrences (white dots) (*modified from* Ontario Geological Survey 2011, 2020 data).

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Kitco 2020. Gold price today, September 28, 2020. https://www.kitco.com/gold-price-today-canada/

HIGHLIGHTS

- **1337 and 23 rare earth element occurrences and prospects open for staking in Timmins and Sault Ste. Marie districts, respectively**
- **Prospects may also contain niobium, copper, apatite, fluorite, and vermiculite**

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Rare Earth Elements—the New Gold?

Introduction

Rare earth elements (REEs) are a group of elements in the periodic table known as the lanthanides. These elements include cerium (Ce), dysprosium (Dy), erbium (Er), europium (Eu), gadolinium (Gd), holmium (Ho), lanthanum (La), lutetium (Lu), neodymium (Nd), praseodymium (Pr), promethium (Pm), samarium (Sm), terbium (Tb), thulium (Tm), and ytterbium (Yb) which are commonly grouped with scandium (Sc) and yttrium (Y) based on their similar chemical characteristics. The REEs are divided into light (LREE), middle (MREE), and heavy (HREE) rare earth elements based on their atomic numbers. Despite their name, REEs are more common within the earth's crust than some major commodities like copper (Cu) and lead (Pb). For example, Ce is more abundant than Cu, while Nd, Pr, and Y are more abundant than Pb.

The 2020 USGS mineral commodity survey reported the global reserves of REEs to be 140 million tons while the worldwide production estimated at 210 thousand tons ("rare earth" USGS, https://pubs.usgs.gov/periodicals/mcs2020/mcs2020-rare-earths.pdf, accessed December 10, 2020). After growing at a compound annual growth rate (CAGR) of 6.4% from 2015 through 2019, Adamas Intelligence forecasts global consumption of magnet REEs (i.e., Nd, Pr, Dy, and Tb) to reach 9.3% in 2020. It should be noted that the rise of COVID-19 has negatively impacted global demand. Nevertheless, with the ongoing reopening of key demand markets for industries including EV traction motors to micromotors and sensors, wind power generators, consumer appliances, cordless power tools, Adamas Intelligence expects demand for most end-users and applications to rebound strongly in 2021 and 2022 and then a steady rise through the end of the decade, Adamas Intelligence (https://www.adamasintel.com/report/rare-earth-magnet-market-outlook-to-2030/ accessed December 10, 2020).

REE usage and price

Rare earth elements commonly occur together and are used in a wide variety of industries as a metal alloy, catalyst, and polishing powder; however, the advancing usage of REEs, especially Nd, Pr, Dy, and Tb, in the production of permanent magnets as magnet feeds, makes them one of the most promising exploration targets in the upcoming years. Furthermore, the price of magnet rare earth oxides determines the economic value of a deposit. The current values are US$58/kg Pr_6O_{11}, US$79/kg Nd_2O_3, US$940/kg Tb_4O_7 and US$290/kg Dy_2O_3 (BAIINFO Rare Earth Price Analysis, November 27, 2020). The main function of Dy and Tb in magnets is to increase heat tolerance; however, the high value of these elements has motivated industries to look for elemental

Azadbakht, Z. 2021. Rare earth elements—the new gold?; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2020-2021, p.45-49.

substitutions. For example, a permanent magnet industry leader, Neo Performance Materials, has developed a method to replace up to 70% of the Nd contents with Ce. As magnet rare earth element prices rise and supplies become progressively scarce through the second half of the decade, the adoption of Ce and/or La bearing magnets will accelerate ("Cerium, Lanthanum and Terbium Will Help Fill the Magnet Rare Earth Gap," Adamas Intelligence (August 19, 2020), https://www.adamasintel.com/ce-la-tb-help-fill-impending-gap/, accessed December 10, 2020). Furthermore, a Chinese financier is now looking into Ce occurrences within northern Ontario, hoping to develop new exploration targets. For more information, please read the full article on Northern Ontario Business (September 9, 2020) at (https://www.northernontariobusiness.com/industry-news/mining/chinese-financier-has-a-keen-eye-for-northern-ontario-cesium-2698524?utm_source=Email&utm_medium=Email&utm_campaign=Email) (accessed December 10, 2020).

REE deposits

Rare earth element deposits are commonly associated with metavolcanic rocks, carbonatite–alkalic rocks, highly-fractionated granitic rocks and pegmatites, clay-laterite, and in some cases tailing dams. However, LREE enriched carbonatites supply more than 80% of global production and are the dominant source of magnet feeds (i.e., NdPr; Adamas Intelligence, https://www.adamasintel.com/report/rare-earth-magnet-market-outlook-to-2030/ accessed December 10, 2020).

Two types of REE bearing deposits occur in Timmins and Sault Ste. Marie districts: 1) carbonatite and 2) alkalic intrusive suites. Carbonatites are defined as igneous rocks containing more than 50% modal primary carbonates and less than 20 wt % SiO_2 by the International Union of Geological Sciences (LeMaitre 2002). On the other hand, alkalic complexes are more granitic in composition and are HREE enriched. Carbonatites are the main source of the REEs and Nb, while alkalic complexes are important sources of Cu, apatite, fluorite, vermiculite, and other commodities (Simandl and Paradis 2018).

What to look for in carbonatites?

There are more than 150 REE bearing minerals in nature; however, just 3, including monazite (LREE PO_4), bastnäsite (LREE CO_3F), and xenotime (HREE PO_4), are currently commercialized and used to produce high-grade REEO by the industry. More importantly, the variety of REE bearing minerals within a deposit is the major factor controlling the value of the deposit (i.e., less variation, higher value).

REE deposits in Timmins and Sault Saint Marie districts

There are 13 carbonatite and alkalic intrusive suites in Timmins and 2 carbonatite complexes in Sault Ste. Marie District (Table 1). Using the unstaked REE occurrences of the mineral occurrences catalogued in the Mineral Deposit Inventory (MDI) database (Ontario Geological Survey 2020), more than 500 and 45 unstaked areas were identified in the Timmins and Sault Ste. Marie districts (Figures 1 and 2; information current to October 16, 2019). There is also a direct relationship between carbonatites and alkalic suites with the observed REE mineralization in both districts. Howells, Mowbray, Hopkins, and Shenango townships have the most unstaked REE occurrences, followed by Clay and Cargill townships within the Timmins District. On the other hand, McMurray, Lastheels, and Bouck townships each have up to 15 REE occurrences open for staking within the Sault Ste. Marie district. It is important to add that carbonatites are REE enriched in the center and Nb enriched in their rims. For example, the latest studies on Seabrook and Firesand carbonatite in Sault Ste. Marie indicated >1 wt % Nb_2O_5 mineralization (Sage 1988h, 1988d; Simandl and Paradis 2018).

Another interesting REE bearing deposit within Timmins District is a tailings dam. In 2016, Pierre Bousquet (Timmins District Geologist) took a few samples from the Agrium mine tailings dam situated southwest of Cargill Township, of Kapuskasing. All the samples are highly enriched in REEs, with total REE content reaching up to 6700 ppm.

Table 1. Known carbonatite and alkalic rock occurrences of Timmins and Sault Ste. Marie districts.

	Name	Township (Twp)	Patented land	Leased land	Reference
Timmins District					
1	Albany Fork	South of Lone Lake Area	No	No	Sage (1987b)
2	Argor	West of Marberg Creek Area	No	Partly	Sage (1988a)
3	Borden	Borden	Yes	No	Sage (1987a)
4	Cargill	Cargill, Cumming	No	Partly	Sage (1988b)
5	Clay-Howells	Clay, Hopkins, Howells, Mowbray	Partly	No	Sage (1988c)
6	Goldray	Yesterday River Area	No	No	Sage (1988e)
7	Hecla-Kilmer	Hecla-Kilmer	No	No	Sage (1988f)
8	Lackner Lake	Lackner, McNaught	Yes	No	Sage (1988g)
9	Martison Lake	South of Ridge Lake Area	No	Partly	Potapoff (1989)
10	Nagagami River Belt	Nagagami River Area	No	No	Sage (1983)
11	Nemegosenda Lake	Chewett, Collins, Pattinson, McGee	Partly	No	Sage (1987c)
12	Shenango	Shenango, Sherlock	No	No	Sage (1987d)
13	Valentine	Valentine	No	No	Sage (1988i)
Sault Ste. Marie District					
1	Firesand River	Twp 28 Range 23, Lastheels	Partly	No	Sage (1988d)
2	Seabrook Lake	Twp 5e, Maeck, Rollins, Twp 4e	No	No	Sage (1988h)

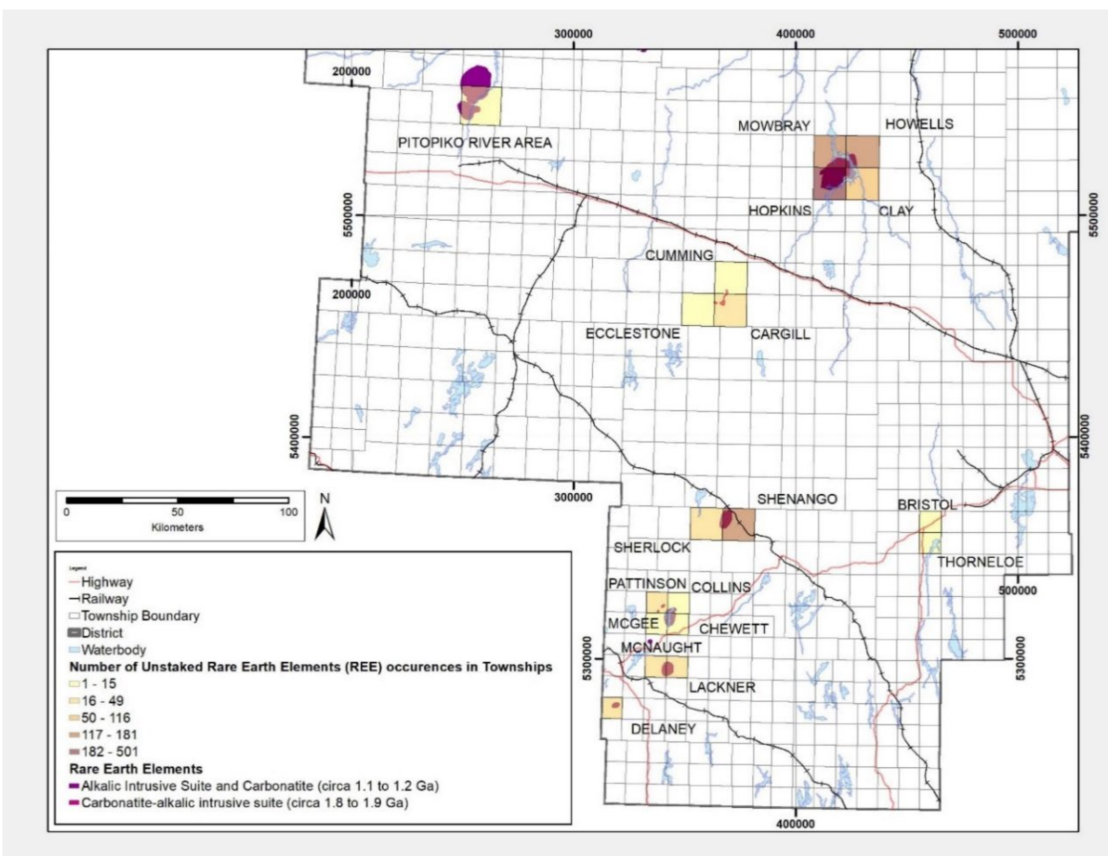

Figure 1. A map of the Timmins District showing the location of unstaked rare earth element occurrences.

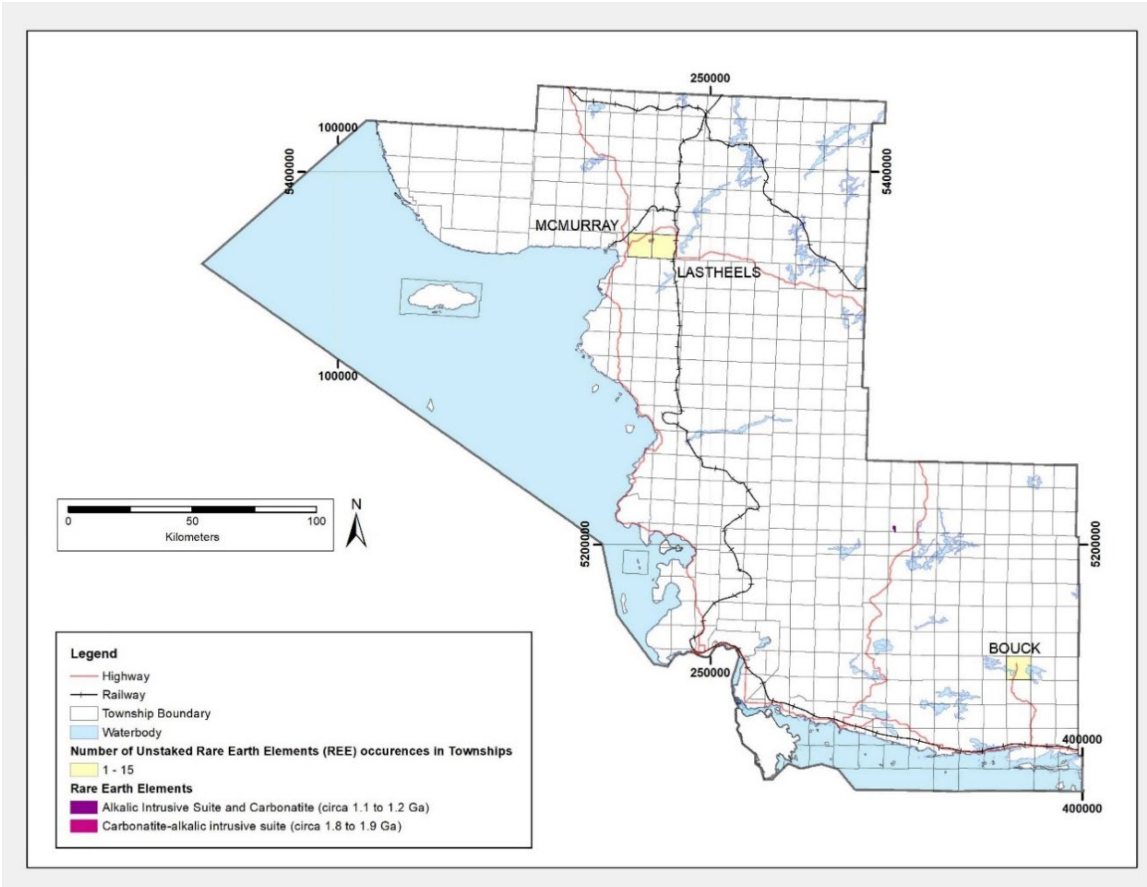

Figure 2. A map of the Sault Ste. Marie District showing the location of unstaked rare earth element occurrences.

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Simandl, George J. and Paradis, Suzanne. 2018. Carbonatites: Related ore deposits, resources, footprint, and exploration methods; Applied Earth Science, v.124, p.123-152.

HIGHLIGHTS

- **Underexplored despite high demand in the Electric Vehicle industry**
- **Good potential for lithium in Chambers Township**
- **Excellent metasedimentary host proximal to a potential "fertile" parental granite**

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Lithium-Cesium-Tantalum (LCT) Pegmatite Potential in the Temagami Area

Cynthia–Chambers–Strathy is a block of 3 contiguous townships within the Temagami Greenstone Belt (TGB) which is itself located approximately 40 km north of the Grenville Province in eastern Ontario. For further description of the TGB, the reader is referred to Moorhouse (1946), Bennett (1978) and Fyon and Cole (1989).

In Chambers Township, Archean mafic to intermediate to felsic and metasedimentary rocks are intruded by the Spawning Lake quartz monzonite stock in the south, and the Chambers–Strathy batholith in the north. Proterozoic Cobalt Group sedimentary rocks unconformably overlie the rocks in the northwest corner of the township. Younger Nipissing diabase dikes and sills intrude all the rocks in the area. Selected mineral occurrences in the area are the R.G. Gilson (copper, zinc, lead, gold) occurrence, the Kokoko (iron) prospect and the Falconbridge DDH CHA-03 (nickel, copper) occurrence in Chambers; the Falconbridge DDH CHA-08 (zinc, copper, lead) occurrence, and the B. Westin (gold) occurrence in the adjacent townships of Cynthia and Strathy, respectively (Figure 1).

The Temagami area remains underexplored for LCT mineralization despite high demand in the electric vehicle industry. In this article, the author aims at highlighting some of the significant characteristics of this class of pegmatite, and how they can be harnessed to help guide exploration efforts in Chambers Township.

LCT pegmatites are granitic rocks that form relatively small igneous bodies and are characterized by large crystals and unique textures, particularly graphic intergrowths (London 2008). The LCT family of pegmatites takes its name from its characteristic enrichment in lithium, cesium, and tantalum, thus, in addition to the lithium minerals petalite, lepidolite, and spodumene, LCT pegmatites may contain the cesium ore mineral, pollucite; the tantalum ore mineral, columbite-tantalite; the beryllium ore mineral, beryl; and the tin ore mineral, cassiterite. LCT pegmatites are the products of extreme fractional crystallization of orogenic granites. Most such granites were derived from metasedimentary rocks (S-type granites) rich in muscovite although certain LCT pegmatites are related to granites derived from igneous rocks (I-type granites) (Martin and De Vito 2005; Bradley et al. 2017).

Suma-Momoh, J. 2021. Lithium–cesium–tantalum (LCT) pegmatite potential in the Temagami area; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2020-2021, p.50-53.

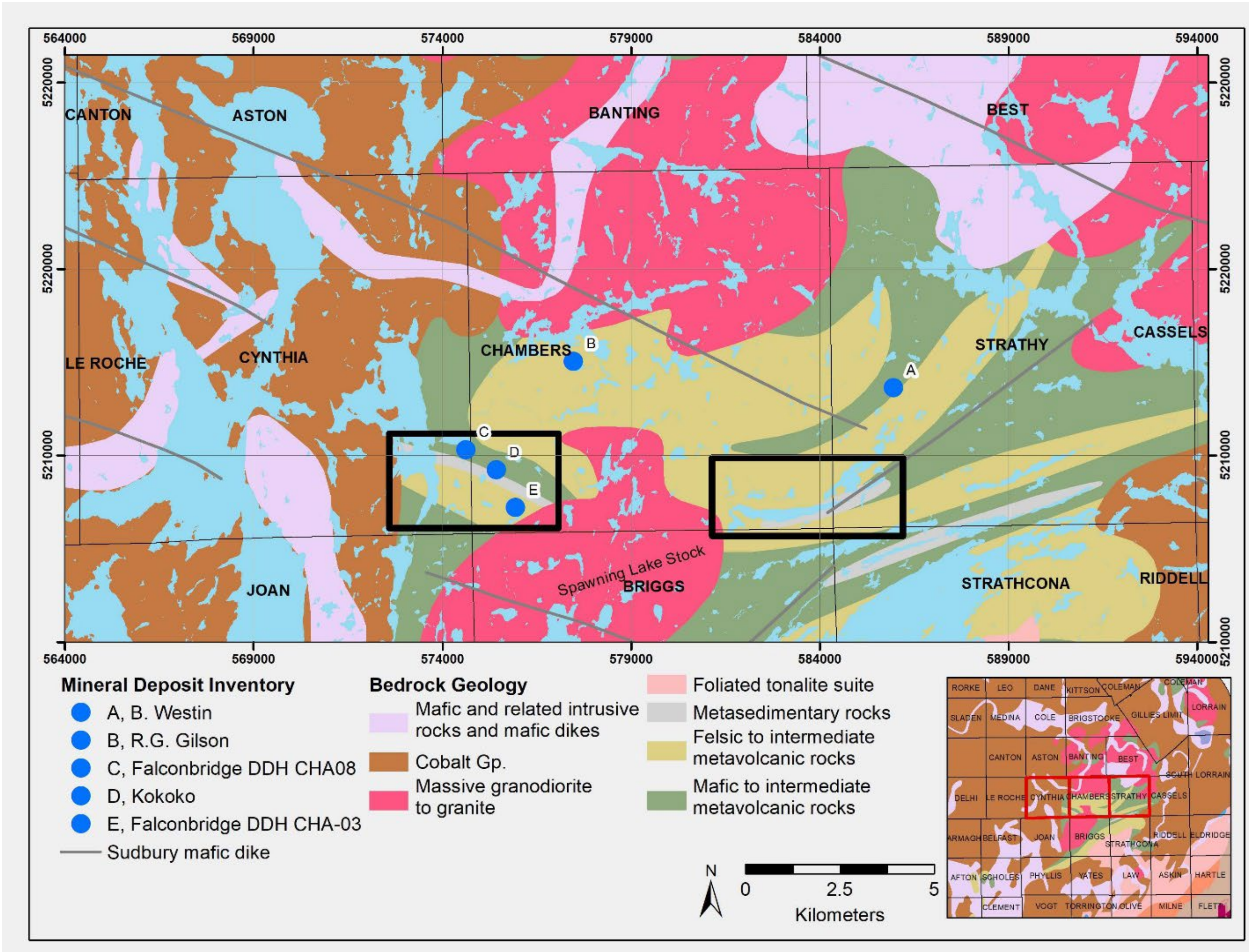

Figure 1. Geology map showing Chambers and surrounding townships, with the locations of selected occurrences *from* the Mineral Deposit Inventory database (Ontario Geological Survey 2020). The inset township map shows the entire Temagami greenstone belt. Geology *from* Ontario Geological Survey 2011. Universal Transverse Mercator (UTM) co-ordinates are provided using North American Datum 1983 (NAD83) in Zone 17.

The following factors and considerations are important regarding mineralization and exploration for LCT pegmatites in Chambers Township:

- The most significant change in LCT pegmatites through Earth's history is that, by far, the largest deposits are Archean in age. Thus, the potential for economic deposits seems greatest in orogens of that age (Bradley and McCauley 2013). This factor is satisfied by Chambers and the TGB in general.
- Most LCT pegmatites intruded and are hosted in metamorphosed sedimentary rocks, typically at low pressure amphibolite to upper greenschist facies (Černý 1992). Bradley and McCauley (2013) add that the metamorphic grade setting is a guide rather than a requirement. In Chambers Township, metasedimentary and metavolcanic rock units are in contact with and in close vicinity (approximately 1 km) of the granitic Spawning Lake stock (*see* rectangular blocks in Figure 1). The Spawning Lake stock is a large body of porphyritic quartz monzonite. It consists of 2 distinct phases: a central coarse porphyritic phase and a medium-grained grey border phase. Narrow dikes of aplite and pegmatite are locally abundant. The central coarse porphyritic phase makes up, by far, the largest part of the stock (Bennett 1978).

- It is relevant to ascertain whether the Spawning Lake stock is "fertile". Fertile granites are identified by the presence of distinctive minerals, such as muscovite, tourmaline, and garnet; by anomalously high concentrations of such trace elements as lithium, cesium, tantalum, rubidium and tin; and by low concentrations of major elements calcium, iron, and magnesium (Selway et al. 2005). Around a fertile granite, the more distal LCT pegmatites are more likely to be enriched in lithium and other compatible elements (Figure 2).
- Weathering of LCT pegmatites can result in both soil anomalies and indicator minerals. Smith and others (1987) demonstrated that arsenic, beryllium, antimony, and tin form a 12 by 20 km halo in lateritic soils around the Greenbushes pegmatite in western Australia, whilst niobium, tantalum, and boron form a smaller, 1 by 5 km halo. Cassiterite, tantalite, elbaite, and spessartine are sufficiently dense and durable to serve as heavy indicator minerals that can be found by panning unconsolidated sediments (Bradley et al. 2017).

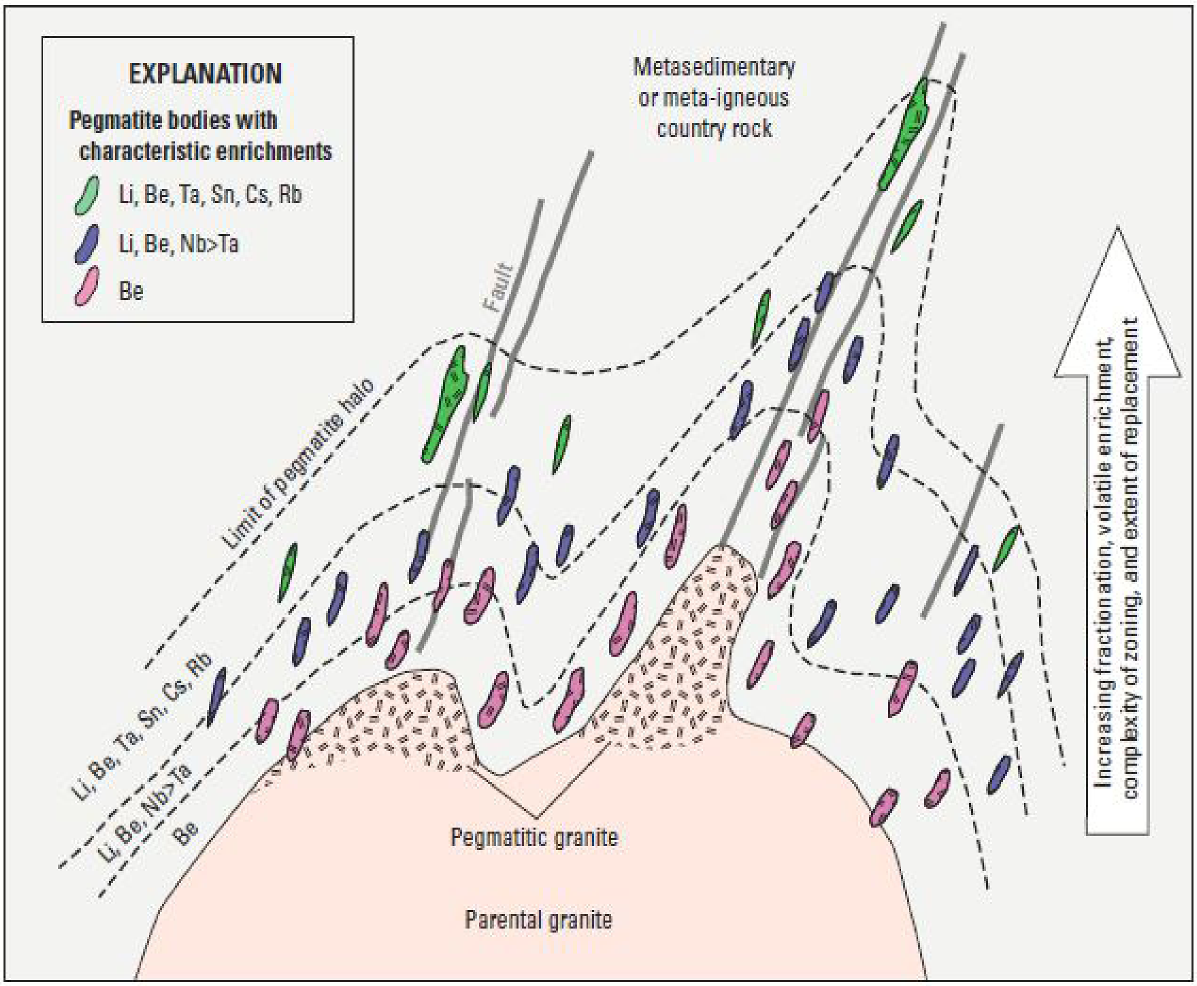

Figure 2. Schematic cross section showing the concentric arrangement of LCT pegmatites (small pink, purple, and green bodies) around a parental granite pluton. In this model, common pegmatites form near the parent, whereas pegmatites with enrichments in incompatible elements (indicated by chemical symbols) and corresponding rare minerals form farther away. Be = beryllium; Cs = cesium; Li = lithium; Nb = niobium; Rb = rubidium; Sn = tin; Ta = tantalum. Diagram *modified from* Bradley et al. (2017).

In summary, historical exploration for LCT pegmatites in the Temagami area is unknown. Chambers Township is located within the Temagami granite–greenstone belt which has undergone regional greenschist to low amphibolite facies metamorphism. Based on these characteristics and the above factors and considerations which are consonant with Superior Province-type rare metal pegmatite deposit model, one might suggest that Chambers Township has the potential to host LCT pegmatites. Against this backdrop, 2 rectangular areas (*see* Figure 1) containing lensoidal metasedimentary rock units proximal to a potential fertile granitic Spawning Lake stock are recommended for the exploration of these critical metals. An exploration program consisting of detailed geological mapping and sampling of any existing distal pegmatitic dikes should be implemented as an initial approach, followed by soil geochemical survey and sampling to delineate potential metal anomalies and zones.

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HIGHLIGHTS

- **Known gold occurrences present a potential for discovery**
- **Suitable geological structures in a favourable host rock**
- **Similar setting to Osisko's Windfall Lake Project (Quebec)**

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Looking for Gold in the Eastern Parts of the Kidd–Munro Assemblage

The Kidd–Munro assemblage (2720 to 2710 Ma), is perhaps better known as a host to the world-class Kidd Creek Mine near Timmins, a giant volcanogenic massive sulphide (VMS) deposit, primarily rich in copper and zinc, as well as the Potter Mine, a smaller equivalent deposit in Munro Township, in the western part of the Kirkland Lake District (Houlé et al. 2010). The purpose of this brief note is to explore the possibility of potential orogenic lode gold mineralization in the eastern parts of this assemblage, and to draw comparisons in terms of the structural, lithological and age settings with Osisko Mining Inc.'s Windfall Lake project in adjacent Quebec (Murahwi and Torrealba 2020).

A simplified geology map of the easternmost part of the Kidd–Munro assemblage is shown in Figure 1. This assemblage is structurally bound to the north by the northern branch Porcupine–Destor fault zone and the older mafic metavolcanic rocks of the Stoughton–Roquemaure assemblage. To the south, the Kidd–Munro assemblage is separated from the younger mafic metavolcanic rocks of the Blake River assemblage by the Porcupine–Destor fault zone (PDFZ). Known gold-bearing mineral deposits are also shown, in addition to those documented in the Mineral Deposit Inventory (MDI) database and drill-hole collar positions for core, kept in the Kirkland Lake Drill Core Library, which report gold values (Ontario Geological Survey 2020a, 2020b).

A similar map is presented in Figure 2, highlighting interpreted geological structures (Berger 2010) and locations of specific mineral occurrences (Ontario Geological Survey 2020a) that report gold mineralization both within and immediately adjacent to the Kidd–Munro assemblage. The reader will note the association between structure and reported gold showings.

Key Elements of the Eastern Kidd–Munro Assemblage

An excellent description of the Kidd–Munro assemblage is provided by Bleeker and van Breemen (2011), who subdivided the 2720 to 2710 Ma assemblage into 4 age groups, each spatially restricted with distinct rock types, volcanic morphologies, geochemical affinities and distinctive base and precious metal prospectivity. These are summarized as follows.

- The 2720 to 2717 Ma group is composed of tholeiitic and transitional mafic, intermediate and rare felsic metavolcanic flows, located mostly in Quebec with minor base metal mineralization.
- The 2717 to 2715 Ma group is a bimodal suite of tholeiitic mafic and high-silica felsic metavolcanic flows and a komatiitic suite (proximal to the Kidd Creek Mine). It is worth noting that the tholeiitic felsic metavolcanic rocks of this age are also host to VMS mineralization, as are the high-silica rhyolite units of this age group.

Chadwick, P.C. 2021. Looking for gold in the eastern parts of the Kidd–Munro assemblage; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2020-2021, p.54-58.

- The 2715 to 2712 Ma group consists mostly of mafic tholeiitic lava flows. Kambalda-style nickel-copper with minor platinum group elements (PGE) mineralization in thick komatiite sequences can be found in this group in addition to being observed within the preceding 2717 to 2715 Ma age group.
- The 2712 to 2710 Ma group consists mostly of tholeiitic and transitional felsic tuffs and is restricted geographically to only a few areas.

In addition to hosting base metals, rocks of the Kidd–Munro assemblage do host epigenetic gold, and these occurrences appear to be strongly controlled by structure. This is particularly the case for the eastern parts of the assemblage, where notable gold occurrences are known to be associated with the dominant PDFZ and include the Canamax 42 zone and the Lightning zone (Holloway Mine), as shown in Figure 1.

Similarities with Osisko Mining Inc.'s Windfall Lake Project

Osisko Mining Inc. is currently advancing its Windfall Lake property, located in the Eeyou Istchee James Bay Territory of northeastern Quebec, and occurring within the Urban–Barry greenstone belt, located in the northern volcanic zone of the Abitibi geological subprovince. A detailed description of this high-grade and potential multi-million ounce gold deposit is presented by Murahwi and Torrealba (2020). The Urban–Barry greenstone belt contains mafic to felsic volcanic rock units and is crosscut by several east-trending and east-northeast-trending shears that delineate major structural domains.

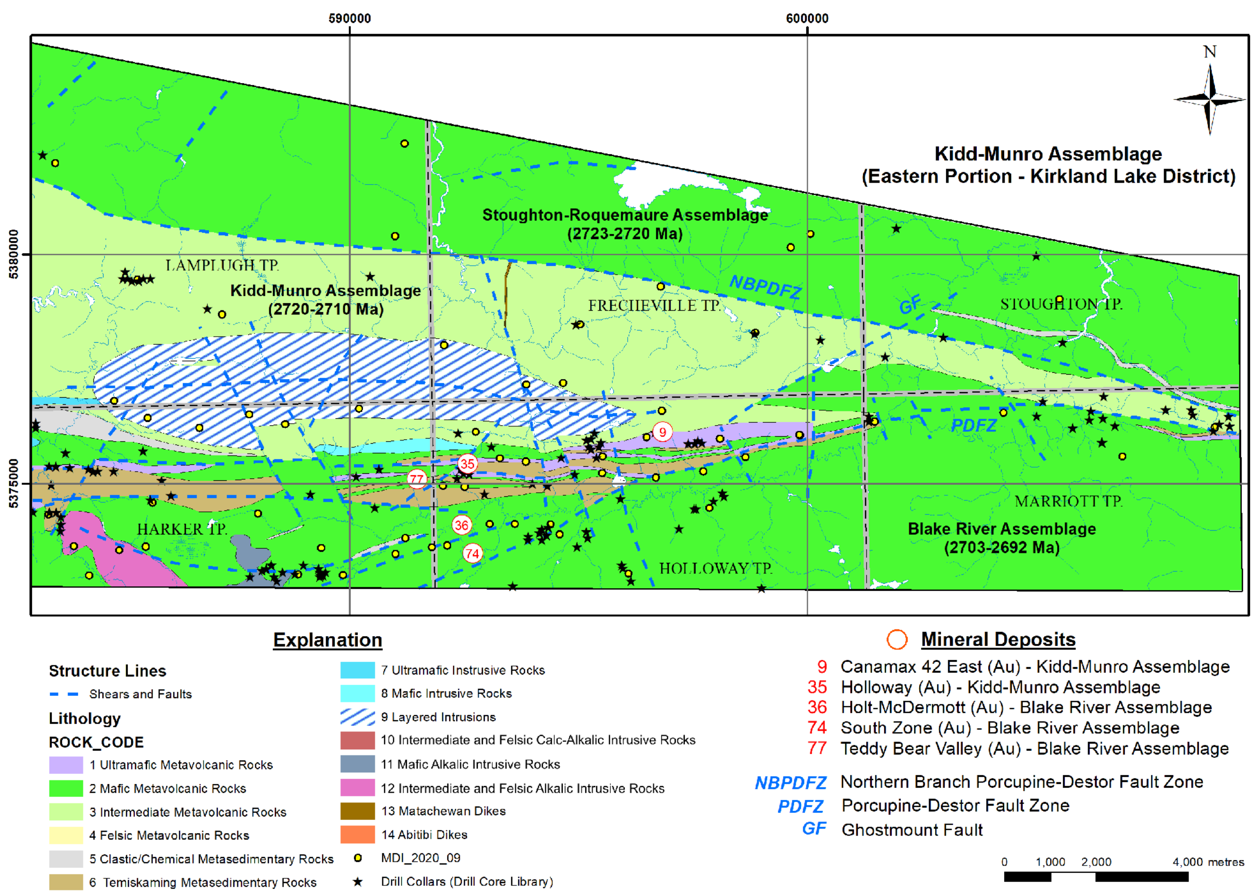

Figure 1. Geological map of the easternmost part of the Kidd–Munro assemblage in the Kirkland Lake District (*modified from* Berger 2010) showing the locations of the gold-related mineral occurrences documented in the Mineral Deposit Inventory (MDI) database (Ontario Geological Survey 2020a) and drill-core collars of core kept at the Kirkland Lake Drill Core Library, the details of which can be found in the Ontario Drill Hole Database (ODHD; Ontario Geological Survey 2020b).

It is the opinion of the author that similar structural domains are present within the eastern parts of the Kidd–Munro assemblage, and that the Riedel-type structural model presented at Windfall Lake to account for the distribution of gold mineralization (Murahwi and Torrealba 2020), can be applied as an exploration model within the Kidd–Munro assemblage as shown in Figure 3. Similarities include the following.

- The host rock is mostly a felsic to intermediate metavolcanic rock.
- The age of the Kidd–Munro assemblage (2720 to 2710 Ma) falls within the more general age of 2735 to 2705 Ma for the northern volcanic zone of the Abitibi greenstone belt at Windfall Lake.
- Both areas are bound to the north and south by major east-trending fault zones and shear zones. At Windfall Lake, these would be the North and Bank faults, with their equivalent being the northern branch PDFZ and the PDFZ in the eastern part of the Kidd–Munro assemblage.
- Cross faults are observed at Windfall Lake, with the east-northeast deformation zones (Riedel shears), and gold mineralization is strongly associated with these crosscutting structures. Similar cross faults are evident in the Kidd–Munro assemblage as shown in Figure 2.

The Reidel shear model, as a significant control for gold deposition at Windfall Lake, is presented in Figure 3, with an idealized equivalent interpretation proposed for the Kidd–Munro assemblage.

The significance of geological structures within the Kidd–Munro assemblage is described by Bleeker and van Breemen (2011), which notes that the northeast-striking faults are generally more brittle-ductile in character, and of less regional extent than the more northerly and northwest-striking faults, and generally more economically significant. The Ghostmount fault, as shown in Figures 1 and 2, for example, is likely to be a splay off the PDFZ. Similar structures appear as splays off the PDFZ, farther to the west of the Ghostmount fault, proximal to a layered intrusive unit.

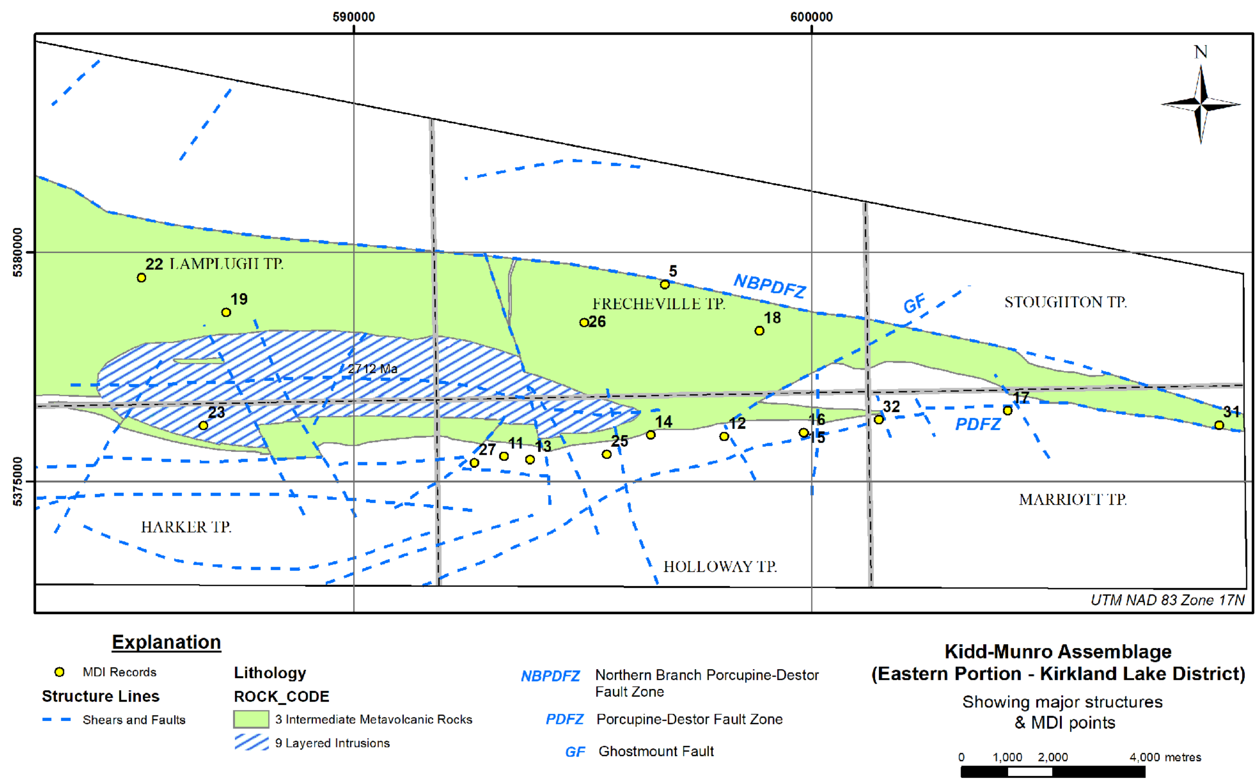

Figure 2. Simplified map of the easternmost part of the Kidd–Munro assemblage in the Kirkland Lake District (*modified from* Berger 2010) highlighting the major geological structures and the locations of documented gold-related mineral occurrences, as keyed to Table 1 (MDI; Ontario Geological Survey 2020a).

Table 1. Documented gold-related mineral occurrences (keyed to Figure 2).

ID	MDI Number	Location Description	Comment
5	MDI32D12SE00035	Diamond-drill hole 88-03	No logs
11	MDI32D12SE00143	Pit	0.10 oz/t gold (grab)
12	MDI32D12SE00028	Diamond-drill holes DDH8a, DDH9 & DDH11	Up to 0.2 oz/t gold
13	MDI32D12SE00020	Adit	Trace gold (grab)
14	MDI32D12SE00008	DDH, underground workings	5.83 g/t Au (resource)
15	MDI32D12SW00219	Drill-hole collar on claim 43078	Discretionary occurrence
16	MDI32D12SE00140	Collar of DDH9	Up to 0.02 oz/t gold
17	MDI32D12SE00014	Diamond-drill hole 49-02-07	910 ppb Au
18	MDI32D12SE00047	Sonic drill-hole 88-06	Trace gold in till
19	MDI32D12SW00068	Sonic drill-hole 85-43	Trace gold in till
22	MDI32D12SW00069	Sonic drill-hole 85-42	Trace gold in till
23	MDI32D05NW00070	Backhoe till sample 85-35B	5000 ppb Au
25	MDI32D12SE00007	Group of 20 diamond-drill holes	Developed prospect
26	MDI32D12SE00048	Sonic drill-hole 88-16	Trace gold in till
27	MDI32D12SE00002	Diamond-drill hole	Up to 0.5 oz/t gold
31	MDI32D12SE00013	Diamond-drill hole 49-04-01	Up to 2.43 g/t Au
32	MDI32D12SE00012	Diamond-drill hole 010-47-1	Average 1.270 ppb Au

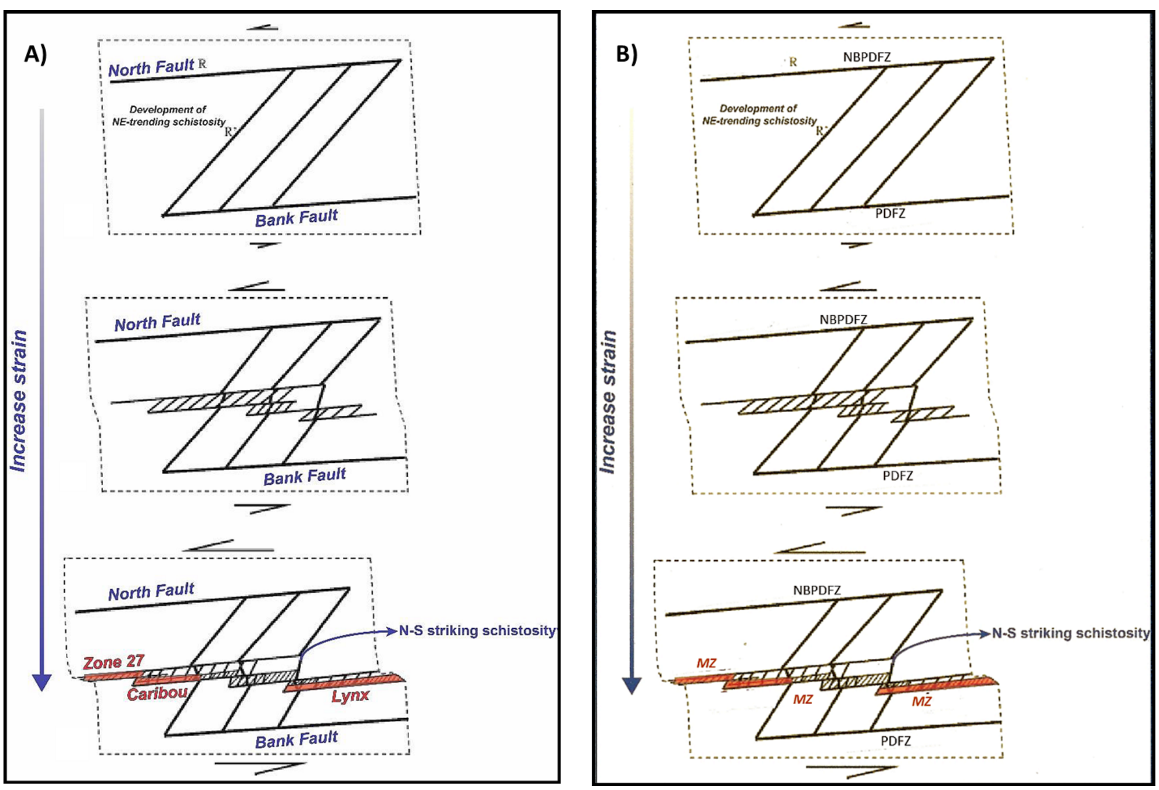

Figure 3. The Riedel-type structural model (R, R′ shears) applied to **A)** the Windfall Lake deposit, Quebec (Murahwi and Torrealba 2020) and **B)** the eastern portion of the Kidd–Munro assemblage. Both figures *modified from* Katz, Weinberger and Aydin (2004). Abbreviations: MZ, mineralized zone; NBPDFZ, northern branch Porcupine–Destor fault zone; PDFZ, Porcupine–Destor fault zone.

To summarize, gold mineralization at Windfall Lake is largely hosted by the following geological settings, all of which are present to some extent in the Kidd–Munro assemblage.

- second-order (D_2) east-northeast deformation zones, concentrated in areas of contrasting rock competencies
- along geometrical boundaries between flat-lying lithological boundaries (layered intrusions) and steep gold-bearing structures
- along strong chemical boundaries between ultramafic (layered intrusions) and felsic rock types

Whilst extensive overburden will pose a challenge in parts of the assemblage area, high-resolution geophysical surveys and the re-assessment of existing publicly accessible geophysical data (Ontario Geological Survey 2003), will be paramount as a desk study, to be supported by overburden–bedrock interface sampling (sonic or rotary air-blast drilling) and subsequent follow-up diamond drilling.

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——— 2020b. Ontario Drill Hole Database; Ontario Geological Survey, Ontario Drill Hole Database, online database, October 2020 update.

Please note: errors, identified in this artilce after publication in January 2021, have been corrected (as of February 2023).

HIGHLIGHTS

- **Vanadiferous titanomagnetite deposits (VTM; iron–titanium–vanadium (FeTiV)) are the principal global source of vanadium**
- **VTM (FeTiV) occur as magmatic accumulations of magnetite and ilmenite within intrusions or metamorphic rocks, possibly remobilized in the latter case**
- **Historically, iron occurrences may not have been analyzed for vanadium, or titanium**
- **In the Grenville, FeTiV deposits have been subjected to metamorphism and hydrothermal activity, potentially modifying their initial magmatic character**

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Vanadium (FeTiV) Potential in the Grenville Province, Sudbury District

Vanadium is classed as a Strategic Mineral Resource (Goldberg et al. 1992) and as a Critical Mineral Resource (CMR) in both Canada (Natural Resources Canada 2019) and the United States (Kelley et al. 2017). The dominant use for vanadium remains in steelmaking, but it is also used in catalysts, ceramics, electronics and vanadium chemicals (Kelley et al. 2017). A recent development that will increase demand for vanadium is the use of vanadium redox batteries (VRB) in green technology.

Vanadiferous titanomagnetite deposits (VTM) are the principal global source of vanadium (Kelley et al. 2017). Titanomagnetite and ilmenite are mined for iron, titanium and vanadium (FeTiV). These mineral deposits occur as layers or lenses in mafic to ultramafic intrusions or metamorphic rocks. The magmatic accumulations of magnetite and ilmenite within intrusions may remain *in situ* or be remobilized during metamorphism. Houle (2019) presented a good overview of magmatic Fe-Ti-V ore systems in the "Geology, genesis, and exploration for magmatic and magmatic-hydrothermal ore deposits" short course at the 2019 Prospectors and Developers of Canada Convention.

The potential for FeTiV deposits has been recognized throughout Ontario (Rose 1973; Cundari and White 2015; LeBaron 2015; Puumala and Campbell 2019, 2020; Bousquet 2020). The area examined here is the Grenville Province in the Sudbury Resident Geologist (RGP) District, which is, for the most part, in the Southern Ontario Mining District. Approximately 13 500 km^2, representing 45% of the Grenville in the Sudbury RGP District, is not affected by surface right holdings or land withdrawals.

Historically, iron occurrences may not have been analyzed for vanadium, or titanium. Of the 20 occurrences listed as being magmatic, metasomatic, metamorphic or hydrothermal (possibly remobilized) in the Ontario Mineral Deposit Inventory (MDI; Ontario Geological Survey 2020a), 5 report iron only as their commodity (Table 1). Fourteen of the documented occurrences rank above "Discretionary Occurrences"; 2 are "Developed Prospects with Reserves": the Titan Property in Angus Township (MDI31L14SW00014) and the Brazeau Property in Papineau Township (MDI31L02NE00010). Resource estimates for the Brazeau (Papineau) Property are not compliant to National Instrument (NI) 43-101 standards (Whiting 2004). Resource estimates for the Titan Property are NI 43101 compliant (Prenn and Pettigrew 2017). On both properties, the FeTiV mineralization occurs as discrete layers or lenses in mafic intrusions, which in turn are hosted by Grenville gneisses. However, intrusions similar to those hosting the deposits occur elsewhere in the Grenville Province. In Lount Township, there are 7 documented iron

Péloquin, A.S. 2021. Vanadium (FeTiV) potential in the Grenville Province, Sudbury District; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2020-2021, p.59-63.

occurrences that report titanium as a primary or secondary commodity, but vanadium was not analyzed. These occurrences are classified as metamorphic or hydrothermal, and are hosted in amphibolite considered to be intrusive in origin (Satterly 1956).

Of the 20 documented FeTiV occurrences in the MDI (Ontario Geological Survey 2020a), 6 "Occurrences" and 4 "Discretionary Occurrences" are on open ground (Mining Lands Administration System (MLAS) data, accessed October 14, 2020; *see* Figure 1; Table 1).

Table 1. FeTiV occurrences in the Grenville Province, Sudbury Resident Geologist Program District. Data *from* Ontario Geological Survey (2020a). (Map # refers to numbers appearing on Figure 1).

Map #	Property Name (township)	MDI Number	Occurrence Status	Commodity (secondary)	Deposit Type	Land Tenure
1	Titan Property (Angus)	MDI31L14SW00014	Developed Prospect With Reserves	iron, titanium (vanadium)	Hydrothermal	Mining Tenure
2	A-Group (Flett)	MDI000000001459	Occurrence	iron (titanium)	Magmatic	Open
3	B-Group (Flett)	MDI000000001460	Occurrence	iron (titanium)	Magmatic	Open
4	C-Group (Flett)	MDI31L13SE00007	Occurrence	iron (titanium)	Magmatic	Open
5	Nichol Occurrence (Flett)	MDI31L13SE00006	Discretionary Occurrence	iron	Hydrothermal	Open
6	Brazeau Prospect (Papineau)	MDI31L02NE00010	Developed Prospect With Reserves	iron, titanium, vanadium	Magmatic	Active Claim
7	Peerless Canadian (Calvin)	MDI31L02NW00006	Discretionary Occurrence	iron (titanium)	Magmatic	Surface Rights
8	Magnetawan Mine (Lount)	MDI31E13SE00006	Developed Prospect Without Reserves	iron (titanium)	Hydrothermal	Surface Rights
9	Lot 17 Con 1 trench (Lount)	MDI31E13SE00021	Occurrence	iron, titanium	Magmatic Metasomatic	Surface Rights
10	J.W. Edwards Lot 145 Con B (Lount)	MDI31E13SE00040	Occurrence	titanium, iron	Magmatic Metasomatic	Open
11	J. W. Edwards Showing (Lount)	MDI31E13SE00039	Occurrence	titanium, iron	Metamorphic	Open
12	Lot 136 Concession A pit (Lount)	MDI31E13SE00032	Occurrence	titanium, iron	Metamorphic	Surface Rights
13	Spring Lake Deposit (Lount)	MDI31E13SE00029	Occurrence	iron, titanium	Metamorphic	Surface Rights
14	Lot 129 Con B pit (Lount)	MDI000000000715	Discretionary Occurrence	iron	Metamorphic	Open
15	Ferrie Iron (Ferrie)	MDI31E12NE00024	Discretionary Occurrence	iron	Magmatic	Surface Rights
16	Lot 29 Concession 8 Iron (Foley)	MDI41H08SE00056	Occurrence	iron (titanium)	Magmatic	Open
17	Tiffany (Bethune)	MDI31E11SE00007	Occurrence	titanium (vanadium)	Magmatic	Surface Rights
18	South Group (Nipissing)	MDI31L04SE00016	Prospect	iron	Hydrothermal	Surface Rights
19	North Group (Nipissing)	MDI31L04SE00017	Discretionary Occur-rence	iron	Hydrothermal	Open
20	Dryden Magnetite (Dryden)	MDI41I07NE00005	Discretionary Occur-rence	titanium, iron	Magmatic	Open

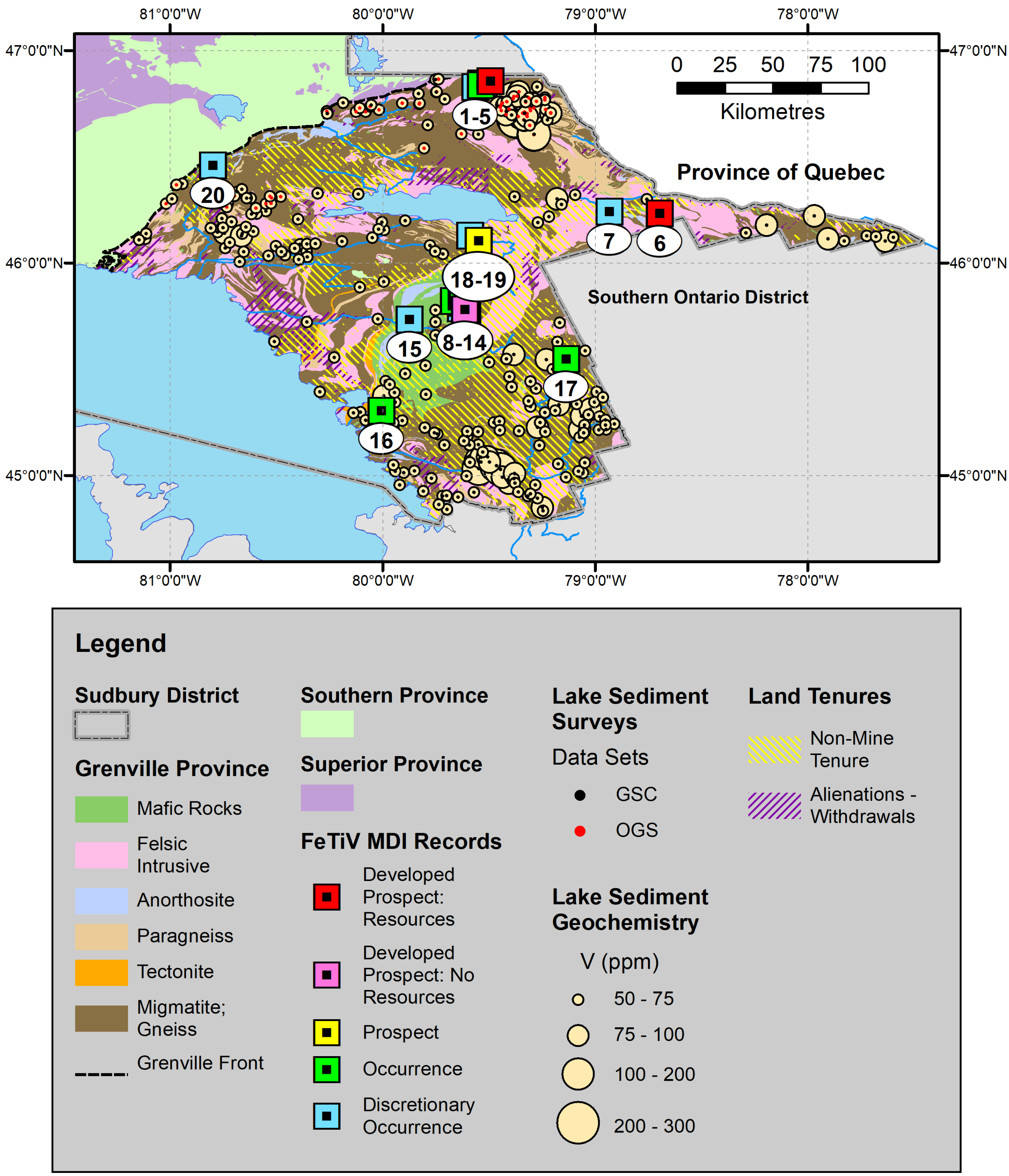

Figure 1. Map of the Grenville Province in the Sudbury Resident Geologist Program District showing the locations of documented FeTiV occurrences (*see* Table 1; data *from* Mineral Deposit Inventory in Ontario Geological Survey 2020a; region straddles UTM zones 17 and 18; geology *from* Ontario Geological Survey 2011).

Lake sediment geochemistry surveys have been undertaken over the Grenville in the Sudbury RGP District, by the Ontario Geological Survey (OGS; Ontario Geological Survey 2020b) and the Geological Survey of Canada (GSC; Hornbrook, Lund and Lynch 1984; Hornbrook and Fiske 1988, 1989). The data sets are available for download online. Figure 1 shows the vanadium results of the surveys. The OGS data used was analyzed by ICP-OES (induced coupled plasma optical emission spectroscopy), and the GSC Data, by AAS (atomic absorption spectroscopy). The data was filtered to include results only for vanadium values greater than 50 ppm; and the 2 data sets are made distinct in Figure 1. The largest concentration of anomalous vanadium values are southeast of the Titan Prospect. A second concentration of anomalous data is near the southern-most border of the Sudbury RGP District.

Recommendations:

- Examine, sample and analyze known iron occurrences to determine whether vanadium and/or titanium are associated with them.
- Examine mafic intrusions and their environs for magmatic FeTiV occurrences and possible metamorphic or hydrothermally remobilized mineralization.
- Examine potential sources for the anomalous vanadium results in the lake sediment surveys.

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HIGHLIGHTS

- **Demand for local supply chains of critical metals at an all-time high**
- **Overlooked REE potential from former uranium–thorium exploration programs**

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Rare Earth Elements in Southeastern Ontario

Background

The development of existing and emerging technologies has driven demand for relatively obscure minerals which contain elements such as lithium (Li), indium (In), tellurium (Te), gallium (Ga), antimony (Sb), beryllium (Be), carbon (C), rare earth elements (REE), uranium (U), thorium (Th), magnesium (Mg) and high-purity silica. Jurisdictions around the world, including China, the United States, the European Union, India, and Japan have each developed a listing of metals that they consider "critical". In January 2020, Canada and the United States finalized the Canada–U.S. Joint Action Plan on Critical Minerals Collaboration in a step to further secure critical supply chains necessary for various industries within both countries (Natural Resources Canada, news release, January 9, 2020). Currently, Canada is an important supplier of 13 of the 35 minerals deemed critical to economic and national security by the United States with the potential to become a reliable source of other critical elements. Thirty-one million dollars in funding has been announced towards building Canada's first rare earth element processing facility in Saskatchewan, with an expected operational date of late 2022 (Saskatchewan Research Council, news release, August 27, 2020).

REE ± Th, U

Mineral deposits within the Central Metasedimentary Belt (CMB) of the Grenville Province (Figure 1) in southeastern Ontario were some of the earliest exploited and, at the time, nationally important mineral deposits (Easton 2016a). These include uranium, thorium, molybdenum and REE bearing pegmatites, skarns, and calcite vein dikes, which are most abundant in the Bancroft and northern Elzevir terranes of the CMB (Easton 1992). One hundred pegmatites within southeastern Ontario are listed by Hewitt (1967) to contain REE and actinide minerals such as uraninite, pyrochlore ("betafite", "ellsworthite", respectively), euxenite, and allanite, among others. These pegmatites, generally mined in small scale operations for feldspar, quartz, and evaluated during uranium–thorium exploration, should also be considered as REE targets. Although rare earth minerals have been recognized and collected for over a century as mineral specimens, there are no records of REE production (Sangster et al. 2009). Reporting of REE content within the southeastern Ontario pegmatites remains sparse despite the common occurrence of REE bearing minerals. Historical mines and mineral collecting occurrences of note include the MacDonald Mine, a feldspar mine in Monteagle Township which contained allanite (Ce), cyrtolite (Y), and ellsworthite (Nb-Ta pyrochlore) and was noted by Ellsworth (1932) as capable of running on REE production alone. The Woodcox Mine is noted

Meek, R.D. 2021. Rare earth elements in southeastern Ontario; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2020-2021, p.64-71.

to have contained large crystals of pyrochlore, calciosamarskite, and columbite (Sabina 1986) and although follow up on REE content was recommended in an assessment report (Donnan 1955), no REE analysis was conducted. The Comet quartz mine (Gole Pegmatite), is a zoned quartz monzonite pegmatite noted for large crystals of yttrium-rich allanite up to 60 cm in diameter as well as fergusonite crystals up to 8 cm in diameter (Hogarth et al. 1983).

More recent Ontario Geological Survey (OGS) activity within the Central Metasedimentary Belt has identified REE mineralization in metasomatic deposits in the Perth and Sharbot Lake areas (Easton and Clark 2013; Easton 2014, 2016a, 2016b; Tessier et al. 2018). These metasomatic deposits include calcite vein-dikes, coarse-grained, pink, calcite-rich rocks, diopsidites, apatite-rich carbonates, and in mica pyroxenites. The carbonate associated, metasomatic, REE mineralization remains an attractive target as these enriched carbonate phases are more conducive to REE extraction in comparison to silicate phases. A preliminary exploration model for these deposits is presented by Easton (2016a) encompassing multiple commodities. These metasomatic deposits were originally mined as sources of phosphate and mica in the early to mid 1900s.

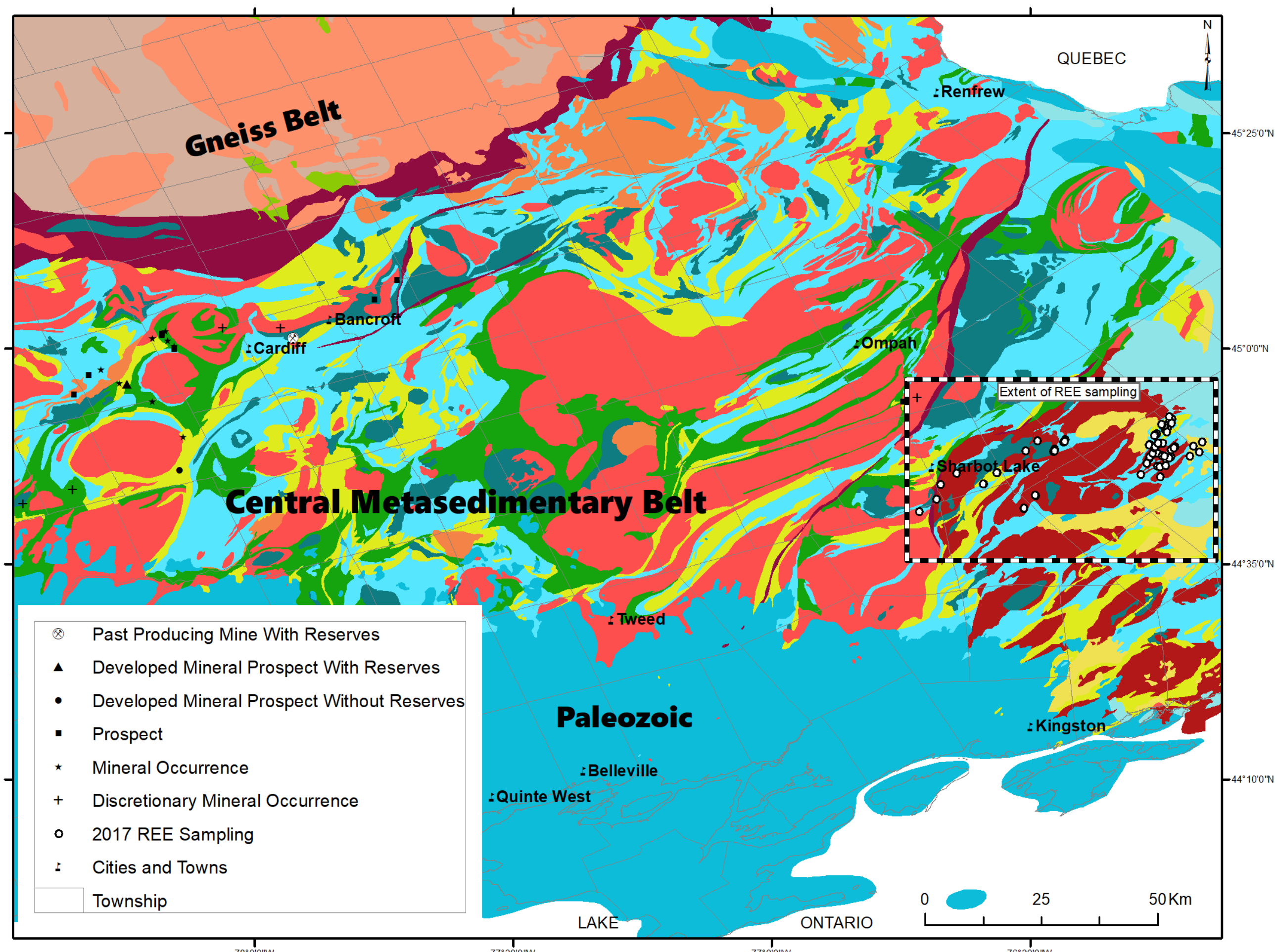

Figure 1. Geological map showing the region of the Central Metasedimentary Belt of the Grenville Province in the Southeastern Ontario District. The locations of documented mineral occurrences with uranium–thorium in drill core with REE potential are shown in the inset; details are given in Table 1 and shown in Figure 2 (sample locations *from* Tessier et al. 2018).

During the 2017 Rare Elements and Rare Earth Elements Project (Tessier et al. 2018), 28 past-producing apatite and mica sites were visited and sampled (Figure 2). These sites consisted of trenches, small open pits and a few limited underground workings. A complex array of vein-dikes and small irregular intrusive bodies which pinch and swell from a few centimeters to up to 6 m in width host the mineralization. Upon examining old excavations, it appears that individual lenses or pods do not exceed 50 m in length. The main intrusive bodies contain irregular offshoots which extend over several metres in all orientations. The main intrusive rock present in during this sampling program consisted of a coarse-grained, buff-pink calcite dominated unit with euhedral biotite, apatite, and diopside crystals in varying proportions and sizes that ranged from 0.5 cm to more than 30 cm. This calcite dominated unit is crosscut locally by vein-dikes of fine-grained diopside, apatite, biotite, and calcite with euhedral diopside and biotite crystals up to 30 cm in diameter. Multiple samples were collected and sent for analyses (Table 1). The average concentration of Ce and La was 248.4 and 131.1 ppm, respectively, with 873 ppm Ce and 403 ppm La results obtained from samples taken from a 50 cm wide pegmatite zone containing biotite, diopside and apatite (*see* Table 1, sample 4).

Table 1. Selected element analysis results from the 2017 Rare Elements and Rare Earth Elements project, data *from* Tessier et al. 2018. Select numbered sites from the table are shown in Figure 2. (UTM zone 18).

Sample No.	Easting	Northing	P_2O_5 (wt. %)	Sr (ppm)	Th (ppm)	U (ppm)	Y (ppm)	Zr (ppm)	Ce (ppm)	La (ppm)
(1) Anglo-Canadian 1	402409	4966770	29.9	2343.9	97	8.9	106.2	24	849	447
(2) Anglo-Canadian West 1	402012	4966299	1.508	290.8	6.8	<1.6	11.5	106.5	68	28
(3) Anglo-Canadian West 2	402035	4966350	0.268	128	<1.5	<1.6	11.8	218.3	34	19
(4) Anglo-Canadian West 3	402035	4966350	36.843	1600.6	121.6	13.3	113.7	26.6	873	403
(5) Baby 1	400672	4958468	0.048	195.7	<1.5	<1.6	9.7	83.3	27	8
(6) Baby 2	400672	4958468	5.695	3827.4	31.2	4.1	88.3	23.3	636	389
(7) Byrne 1	399973	4961191	0.194	785.2	5.2	<1.6	159.7	91.9	155	65
(8) Byrne 2	399973	4961191	25.23	1731.2	48.7	5.6	58.7	27.5	478	253
(9) Cantin 1	407129	4961386	4.781	219.9	26.4	2.5	32.9	57.8	303	162
(10) Cantin 2	407118	4961378	9.981	333	33.1	3.3	20.9	413.4	135	69
(11) Cordick 1	402276	4965833	19.238	1470.6	61.6	7.5	50.5	111.4	404	192
(12) Cordick 2	402276	4965833	1.162	167.2	5	<1.6	10.5	117.2	42	21
(13) E.Shultz Property 1	401922	4967232	0.788	84.4	<1.5	<1.6	2.3	3.6	<15	<7
(14) E. Shultz Property 2	401932	4967210	0.125	86.7	<1.5	<1.6	2.6	6.9	<15	<7
(15) E. Smith Mine 1	399564	4963122	0.509	72.9	<1.5	<1.6	13.4	89.6	45	22
(16) E. Smith Mine 2	399540	4963050	0.041	298.6	<1.5	<1.6	5.1	22.3	<15	7
(17) E. Smith Mine 3	399540	4963050	0.039	364.1	<1.5	<1.6	2.5	108.3	<15	<7
(18) E. Smith Mine 4	399518	4963024	0.107	100	<1.5	<1.6	7.5	94.3	34	11
(19) Hanlon 1	400216	4961269	5.19	277.4	16.4	2.5	21	54.3	101	41
(20) Hanlon 2	400319	4961230	2.527	388.6	7.1	<1.6	15.9	163.5	69	34
(21) Hanlon West 1	399910	4961002	0.075	2070.7	2.6	<1.6	45.5	69.8	322	198
(22) Hanlon West 2	399910	4961002	0.036	2467.6	4.2	<1.6	63.4	41.3	468	280
(23) Hanlon West 3	399910	4961002	0.005	72.5	<1.5	<1.6	8.1	62.3	25	8
(24) MacLaren 1	400748	4965436	0.142	1043	14.1	2.9	105.7	456.3	117	59
(25) MacLaren 2	400748	4965436	15.883	579	31.6	4	36.9	60.1	205	90
(26) MacLaren 3	400748	4965436	0.035	60.5	<1.5	<1.6	2.6	155.6	<15	<7
(27) MacLaren 4	400691	4965481	3.909	322	15.6	<1.6	23.8	135.6	139	67
(28) MacLaren 5	400691	4965481	0.086	656.6	4.2	<1.6	5.3	318.5	29	24
(29) Mahon 1	402107	4959800	10.744	837.3	17.2	1.7	29.3	83.7	166	75
(30) Mahon 2	402107	4959800	4.681	4012.2	8.1	<1.6	73.4	53.7	528	299
(31) Martha/Munslow 1	399428	4960171	11.782	2461.1	28.2	2.7	75.7	37.3	568	329
(32) Martha/Munslow 2	399428	4960171	0.044	84.6	<1.5	<1.6	4.4	94.8	<15	<7

Table 1. cont'd.

Sample No.	Easting	Northing	P_2O_5 (wt. %)	Sr (ppm)	Th (ppm)	U (ppm)	Y (ppm)	Zr (ppm)	Ce (ppm)	La (ppm)
(33) Matheson Bell 1	398135	4956725	0.165	164.9	<1.5	<1.6	13.3	64.6	45	32
(34) M. Philips Mine 1	401140	4956150	0.017	77.7	<1.5	<1.6	5.6	74.9	20	9
(35) M. Philips Mine 2	401140	4956150	0.103	375.8	5.8	<1.6	6.6	43.8	56	24
(36) M. Philips Mine 3	401143	4956155	0.647	228.9	3.2	<1.6	12.9	75.2	47	23
(37) Nobles Bay 1	402758	4960486	6.86	4429.8	33.3	<1.6	82.5	34.2	679	416
(38) Nobles Bay 2	402758	4960486	12.09	1229.7	46.7	5.9	122.8	18.4	826	518
(39) Noble & Watts Property	405696	4960487	0.06	107.6	<1.5	<1.6	22.2	44.2	49	20
(40) Old Adams 1	399579	4960434	2.943	3258.3	9.4	1.6	69.8	26.2	505	291
(41) Old Adams 2	399579	4960434	0.064	368.8	<1.5	<1.6	11.7	144.5	41	18
(42) Old Anthony 1	400778	4961277	7.877	746.6	19.7	<1.6	92.2	7	673	396
(43) Old Anthony 2	400778	4961278	1.059	257	4.1	<1.6	25.5	186.1	59	26
(44) Otter 1	399992	4961235	28.571	1132	90.9	14.9	114.3	20	813	451
(45) Otter 2	399992	4961235	4.465	352.1	11.7	<1.6	21.7	142.9	107	55
(46) Roadcut CR21 1	402549	4960227	0.814	2235.3	3.1	<1.6	27.6	30.2	197	102
(47) Roadcut CR21 2	402549	4960227	0.545	1827	2.7	<1.6	15.9	25.2	128	67
(48) Silver Queen 1	401025	4958376	37.875	2545.9	95.3	8.8	95.3	23.9	706	365
(49) Silver Queen 2	401025	4958376	3.579	1737.2	13	<1.6	47	647.4	177	89
(50) Silver Queen 3	401025	4958376	0.803	69.1	2.6	<1.6	8.1	32.1	41	10
(51) Silver Queen 4	401025	4958376	1.4	1942.4	6	<1.6	30.5	26.3	247	140
(52) Silver Queen 5	401025	4958376	22.934	1481.2	32.2	4.7	87.4	15.5	530	277
(53) Crow Lake 1	374070	4955117	0.94	74.6	<1.5	<1.6	15.8	89.2	34	22
(54) Crow Lake 2	374070	4955117	18.987	480.4	55.5	9.6	53.1	29.6	102	56
(55) Crow Lake 3	373972	4955085	0.053	1519.8	4.8	<1.6	94.8	26.4	342	222
(56) Orser-Kraft 1	380607	4962080	0.008	120.6	3.1	10.1	66.6	24.5	<15	<7
(57) Orser-Kraft 2	380602	4962147	0.012	118.4	5.5	15.4	120.4	232.8	<15	<7
(58) Orser-Kraft 3	380602	4962147	0.004	126.8	<1.5	28.1	26.2	102.1	<15	<7
(59) Maclaren 1	380083	4949712	0.369	462.2	5.4	<1.6	26.7	39.2	85	55
(60) Maclaren 2	380083	4949712	0.146	443.4	37.5	4.7	70.8	114.6	181	91
(61) Maclaren 3	380076	4949830	6.05	289.7	18.5	2.8	72.4	27.6	238	117
(62) Maclaren 4	380076	4949830	6.579	363.1	30.7	4.9	75.6	142.2	310	172
(63) Maclaren 5	380076	4949830	7.591	241.2	16	2.9	49.5	79.3	191	92
(64) Hollywood, Tom 1	367433	4955110	0.27	187.1	3.6	<1.6	23.7	547.9	34	16
(65) Hollywood, Tom 2	367433	4955110	1.284	159.7	5.4	<1.6	32.9	440	92	59
(66) Christie Lake 1	384851	4961855	0.015	167.8	<1.5	<1.6	4.6	142	<15	8
(67) Christie Lake 2	384851	4961855	0.032	143.3	115.7	30.1	53.8	235.2	32	11
(68) Christie Lake 3	384851	4961855	0.616	519.1	17.4	7.4	69.3	130.3	184	100
(69) Christie Lake 5	384851	4961855	0.008	234.8	12.1	39	12.4	155.1	<15	<7
(70) Christie Lake 6	384988	4961991	0.015	285.8	<1.5	<1.6	92.1	55	225	125
(71) Christie Lake 7	385077	4962348	0.009	527.9	16.7	24.4	8	35.8	<15	<7
(72) Christie Lake 8	385077	4962348	0.008	119	2.8	32.7	7.1	10.9	<15	<7
(73) Christie Lake 9	384988	4961991	0.014	208.6	<1.5	<1.6	89.8	54.5	144	78
(74) Eagle Lake 1	364115	4949292	15.735	773.6	35.5	6.2	121.5	162.5	399	212
(75) Eagle Lake 2	364115	4949292	0.205	486.1	3.3	<1.6	34.5	226.2	42	26

Within the Grenville Province, anomalous zones identified from airborne radiometric surveys have correlated well with uranium–thorium mineralization (Easton 1992) and may also indicate the presence of pegmatites or metasomatic deposits containing REE associated with uranium–thorium mineralization. Uranium–thorium mineralization is concentrated predominantly within the Central Metasedimentary Belt in areas containing major structures (Easton 1992) and has been the subject of thorough exploration efforts over the last century; however, little attention has been paid to associated REE mineralization. Due to the resistant nature of most REE minerals, overburden geochemistry, and mineral dispersion train mapping may assist in prospecting. A search of the Ontario Geological Survey's Mineral Deposit Inventory (2020) for "uranium" and "thorium" within the Southeastern Ontario District gave 318 results, of which 25 have drill core stored at the Tweed Drill Core Library (DCL) (Figure 2).

The REE potential of these pegmatite and metasomatic deposits have largely been overlooked and warrants renewed exploration. The Tweed DCL is one of 7 administered by the Resident Geologist Program (RGP) across the province and hosts over 250 000 m of drill core from 3420 drill holes in southern Ontario. The Tweed DCL contains core from many areas of the Central Metasedimentary Belt including drill core from many uranium prospects that also have potential for REE and remains a great resource to quickly and inexpensively cover a large area of southern Ontario. Table 2 summarizes drill core stored at the Tweed DCL previously drilled for uranium and thorium which may have REE potential.

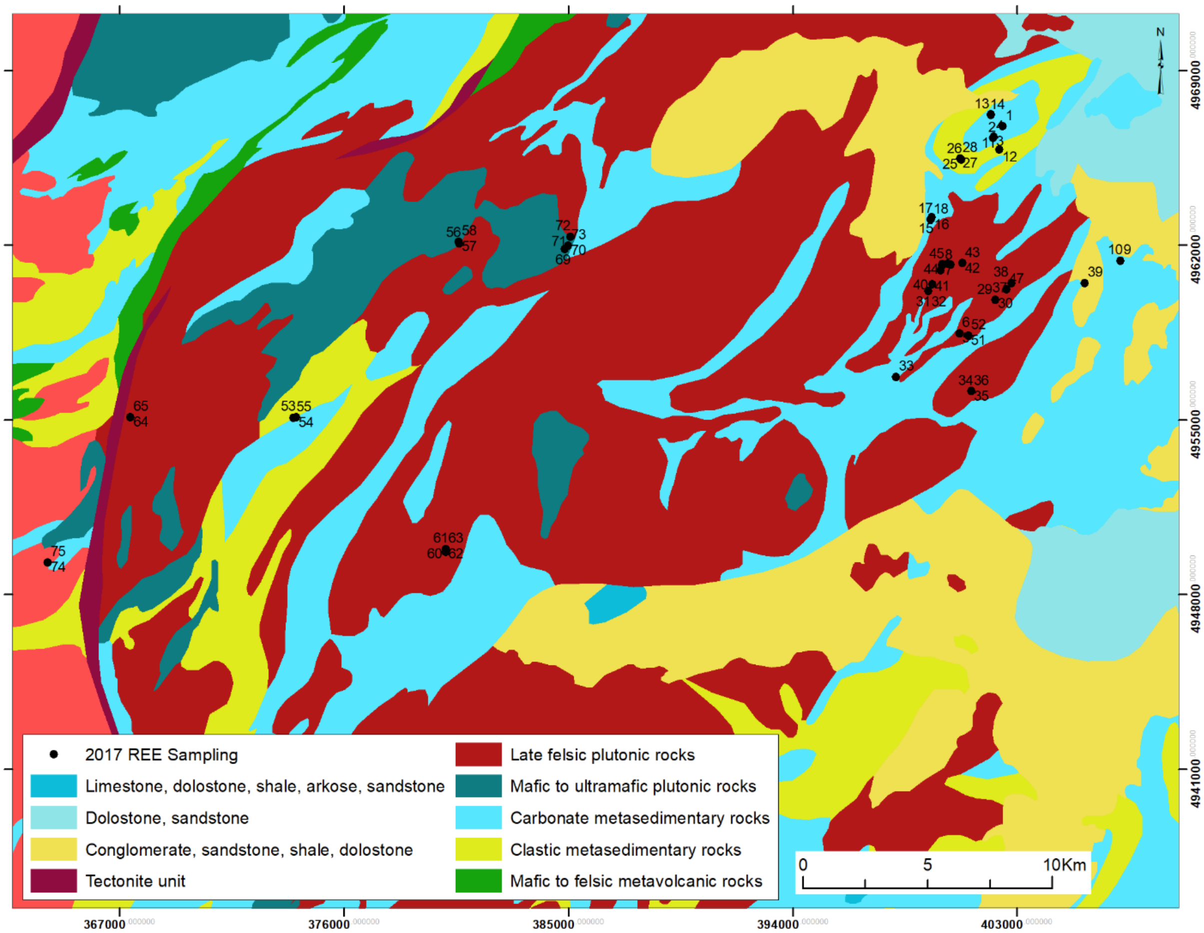

Figure 2. Geological map (inset from Figure 1) depicts the locations of documented mineral occurrences with uranium–thorium in drill core with REE potential, now stored at the drill core library in Tweed, Southeastern Ontario District (sample locations *from* the 2017 Rare Elements and Rare Earth Elements Project, *see* Tessier et al.). Select sites (numbered) from Table 1 are shown on the map.

Table 2. Summary of drill core stored at the Tweed Drill Core Library that are documented to contain uranium–thorium, in the Central Metasedimentary Belt (Grenville Province) of the Southeastern Ontario District; data from MDI, Ontario Geological Survey 2020.

MDI	Name	Status	Township	Commodity: Primary (secondary)	Zone	Easting	Northing	Assessment File No.	DCL File No.
MDI31D16NE00184	Anstruther	Occurrence	Anstruther	Uranium	17	721334	4975337	Anstruther #86	BT0412-417
MDI31D16SE00059	Farcroft	Developed prospect with-out reserves	Anstruther	Uranium	17	725960	4960740	Anstruther # 27	BT0574
MDI31D16SE00087	Eels Creek	Occurrence	Anstruther	Uranium	17	726262	4967824	Anstruther #61, 73, 85	BT0305-338
MDI31D16NE00165	Kenmac Chibougamau	Prospect	Cardiff	Thorium, Uranium	17	724255	4986679		BT0707-711
MDI31E01SE00218	Halo (Pyroxenite)	Occurrence	Cardiff	Uranium	17	722784	4990521		BT0243-252
MDI31E01SE00219	Halo (South Zone), Hogan	Occurrence	Cardiff	Uranium (Niobium, Thorium)	17	724189	4987326		BT0243-252
MDI31E01SE00220	Halo #2 Adit, Hall Lake Zone	Prospect	Cardiff	Uranium (lanthanum, Molybdenum, Gado-linium, Zircon (metal), Cerium, Ytterbium, Dysprosium, Thorium, Yttrium)	17	722226	4989677		BT0243-252
MDI31E01SE00221	Halo #1 Adit, Northwest Zone	Prospect	Cardiff	Uranium (Cerium, Gadolinium, Yttrium, Lanthanum, Ytterbium, Dysprosium, Thorium, Molybdenum, Zircon (metals)	17	722255	4989977		BT0243-252
MDI31E01SE00233	Cardiff (South Zone)	Occurrence	Cardiff	Fluorite, Uranium (Thorium)	17	720848	4988847		BTO201-242
MDI31E01SE00258	Halo (Bald Mountain),	Occurrence	Cardiff	Uranium	17	723227	4988497		BT0253-254
MDI31E01SE00260	Kerr Addison Group J, Cam Property, Cam-Bancroft Adit, South Zone	Discretionary occurrence	Cardiff	Uranium	17	731468	4991510		BT0673-681, 743-816
MDI31D09NW00084	Quebec Uranium Mining Corporation	Discretionary occurrence	Cavendish	Uranium	17	709710	4956002		BT06569-573
MDI31F04NE00067	Mell-Quirke (Barton)	Prospect	Dungan-non	Uranium, Thorium	18	285809	5001238		BT00682-692

Table 2. cont'd

MDI	Name	Status	Township	Commodity: Primary (secondary)	Zone	Easting	Northing	Assessment File No.	DCL File No.
MDI31F04SE00036	Jayfran-Pipawa 2000, Jayfran-1990, Pipawa-1990	Prospect	Dungannon	Nepheline Syenite, (Uranium)	18	282250	4997211		BT0401-411, 819-825
MDI31F04SW00037	Faraday, Madawaska	Past producing mine with reserves	Faraday	Uranium, Thorium	18	269546	4989426		BT0500-672
MDI31F04SW00306	Mercier, Goldhawk (north) occurrence, Harper-Hall-Mercier	Discretionary Occurrence	Faraday	Uranium	18	267721	4991636		BT0084-090
MDI31D09NW00116	Halas	Discretionary Occurrence	Galway	Uranium	17	702261	4952774		BT0137-149, 575-581
MDI31D16NW00213	British Molybdenite, Mandarin Glamorgan Occurrence, Mandarin Occurrence	Prospect	Glamorgan	Uranium, Molybdenum (Feldspar (non-metals), Nepheline Syenite	17	709263	4976488		BT0150-169
MDI31D16NW00204	Canadian All Metals Explorations Limited, Track Showing	Prospect	Monmouth	Uranium (Rare-Earth Elements)	17	711364	4980706		BT0268-304
MDI31D16NW00333	Stratmat, Tory Hill Prospect	Occurrence	Monmouth	Uranium	17	716128	4979118		BT0170-172, 359-365
MDI000000002441	McCue Lake	Prospect	Monmouth	Uranium	17	712929	4982026		BT0338-346,347-358, 366, 367
MDI31D16NE00143	Blue Rock, Amalgamated Rare Earth # 2 Prospect	Developed prospect with reserves	Monmouth	REE, Uranium	17	717307	4979025		BT0255-267, 368-379
MDI31C15NE00081	Gamson	Discretionary occurrence	Palmerston	Uranium	18	364311	4973805		TW0217-220
MDI000000002444	Jupiter Project	Prospect	Palmerston	Uranium	18	362139	4973050		TW2561-2565
MDI000000002446	Mercury Project	Prospect	Palmerston	Uranium	18	362612	4971495		TW2552-2560

Summary

The rare earth element potential of the Southeastern Ontario District has been largely overlooked during past mining and exploration efforts for uranium–thorium, molybdenum, and feldspar. Rare earth element mineralization is also present as carbonate phases in the Frontenac, Perth, and Sharbot Lake areas. There is a vast resource of data from previous mining and/or exploration activity available through the Tweed Resident Geologist office and DCL available which has great potential to significantly reduce early exploration costs and refine REE targets in the area.

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HIGHLIGHTS

- **Southern Ontario remains a strong competitor in the natural stone market because of its diverse geology and proximity to well-developed residential markets and transportation routes**
- **Increasing appreciation for the aesthetics and durability of natural stone in home improvement projects**
- **Dimension stone is a "green" building material because of its inherent characteristics**
- **The new "Ontario-Made" program could significantly increase the demand for locally made dimension stone products sourced from southern Ontario quarries**

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The Beautiful Building Stones of Southern Ontario

The stone industry in Ontario dates back over 200 years beginning with early European settlement (LeBaron 2020). Today, southern Ontario remains a strong competitor in the stone industry with its proximity to well-developed residential markets and excellent transportation routes via roads, rail and Great Lakes shipping (LeBaron 2020). The dimension stone industry in southern Ontario is as diverse as the geology, currently hosting 60 active quarries taking advantage of the distinctly different lithologies that make up this region (Figure 1). These quarries produce a variety of products such as landscaping stone, amour stone, flagstone, ashlar and polished tiles (LeBaron 2020).

Market Outlook

In January 2020, Allied Market Research released a report stating the global natural stone market, worth US$35,120.1 million in 2018, is projected to increase to US$48,068.4 million by 2026 with an anticipated compound annual growth rate (CAGR) of 3.9% from 2019 to 2026. This growth in the natural stone market is driven by a rise in the standard of living leading to more disposable income for home improvement projects. These projects highlight a greater appreciation for the aesthetics and durability of natural stone for interior and exterior home remodeling. For example, the popularity of outdoor "rooms" with stone walls, floors and fireplaces as extensions of the house. Another driving factor is an increase in residential and civic infrastructure projects which, rely heavily on the global stone market (Natural Stone Market by Type (Marble, Granite, Limestone, and Others) and Application (Flooring, Memorial Arts, Wall Cladding, and Others): Natural Stone Market By Type | Global Opportunity Analysis and Industry Forecast, 2019-2026; Allied Market Research (2019); www.alliedmarketresearch.com accessed December 8, 2020).

The Advantages of Natural Stone as a Building Material

One of Toronto's oldest buildings is the Gibraltar Point lighthouse built in 1808-09. This lighthouse is constructed of crinoidal dolomitic limestone from Queenston, Ontario (Middleton et al. 2009) and is a testament to the strength and durability of stone. Other inherent characteristics of stone such as low maintenance, aesthetic appeal, high thermal mass (ideal for passive heating and cooling systems), and recycling potential all contribute to its increasing popularity in building projects (LeBaron 2020). Also, these properties make stone a "green" building material, one of the criteria for the Leadership in Energy and Environmental Design (LEED) rating system. The LEED rating system awards points for

Mancini, L.A. 2021. The beautiful building stones of southern Ontario; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2020-2021, p.72-77.

meeting or exceeding environmental standards in the categories of site selection, locally sourced and types of building materials, water management and energy efficiency (LeBaron 2020). LEED Canada defines “local” as an 800 km radius from the project site. For projects in southern Ontario, this radius includes all quarries from Lake Erie to Sudbury and Windsor to Cornwall (LeBaron 2020). More information on LEED can be found on the Canada Green Building Council website (www.cagbc.org).

On July 10, 2020, Premier Doug Ford announced the new “Ontario-Made” program created by the Canadian Manufacturers and Exporters (CME). The program is designed to connect consumers and supply chain partners to manufacturers of Ontario-made products through a single directory (https://news.ontario.ca/opo/en/2020/07/proudly-supporting-ontarios-manufacturing-sector.html, accessed December 8, 2020). This program has the potential to significantly increase the demand for locally made natural stone products that are sourced from southern Ontario quarries.

Southern Ontario Dimension Stone Potential

In 1990 LeBaron et al. did an extensive research program of building stone potential in eastern Ontario (Figure 2). More than 200 prospects, mainly plutonic rocks and some limestones and marbles, were examined within the Central Metasedimentary Belt (CMB) of the Grenville Province (LeBaron et al. 1990). The rocks were evaluated for dimension stone potential by colour, texture, hardness, deleterious minerals, and jointing (determines quarry block size), the same criteria used by the natural stone industry. Eighty-six prospects in the Precambrian and Paleozoic rocks within the CMB were found to have medium to good dimension stone potential and are recommended for further exploration. This report highlights 24 out of the 86 sites. Figure 2 shows the townships in which the 86 prospects are located, the townships containing the 24 prospects in this report are outlined with dotted lines.

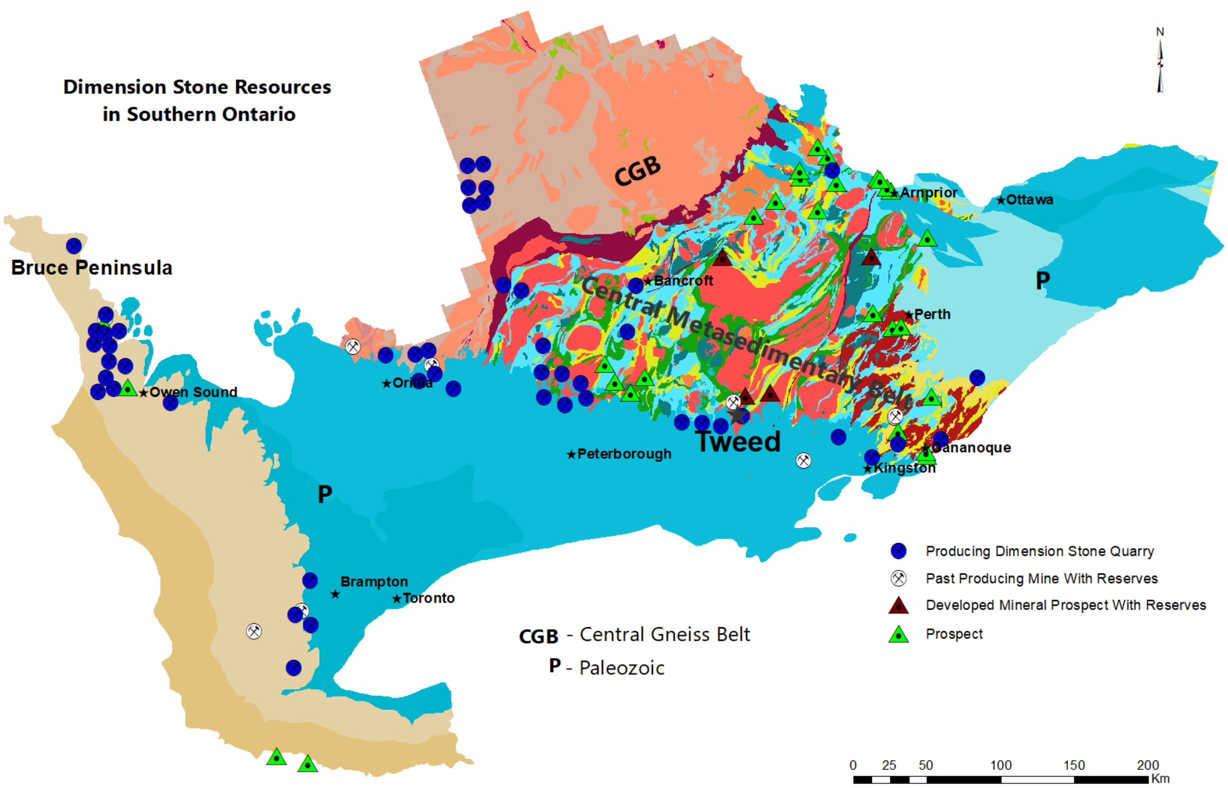


Figure 1. Simplified geological map of southern Ontario showing locations of active quarries producing quarries and potential prospects mainly within the Central Metasedimentary Belt. Map modified *from* LeBaron (2020).

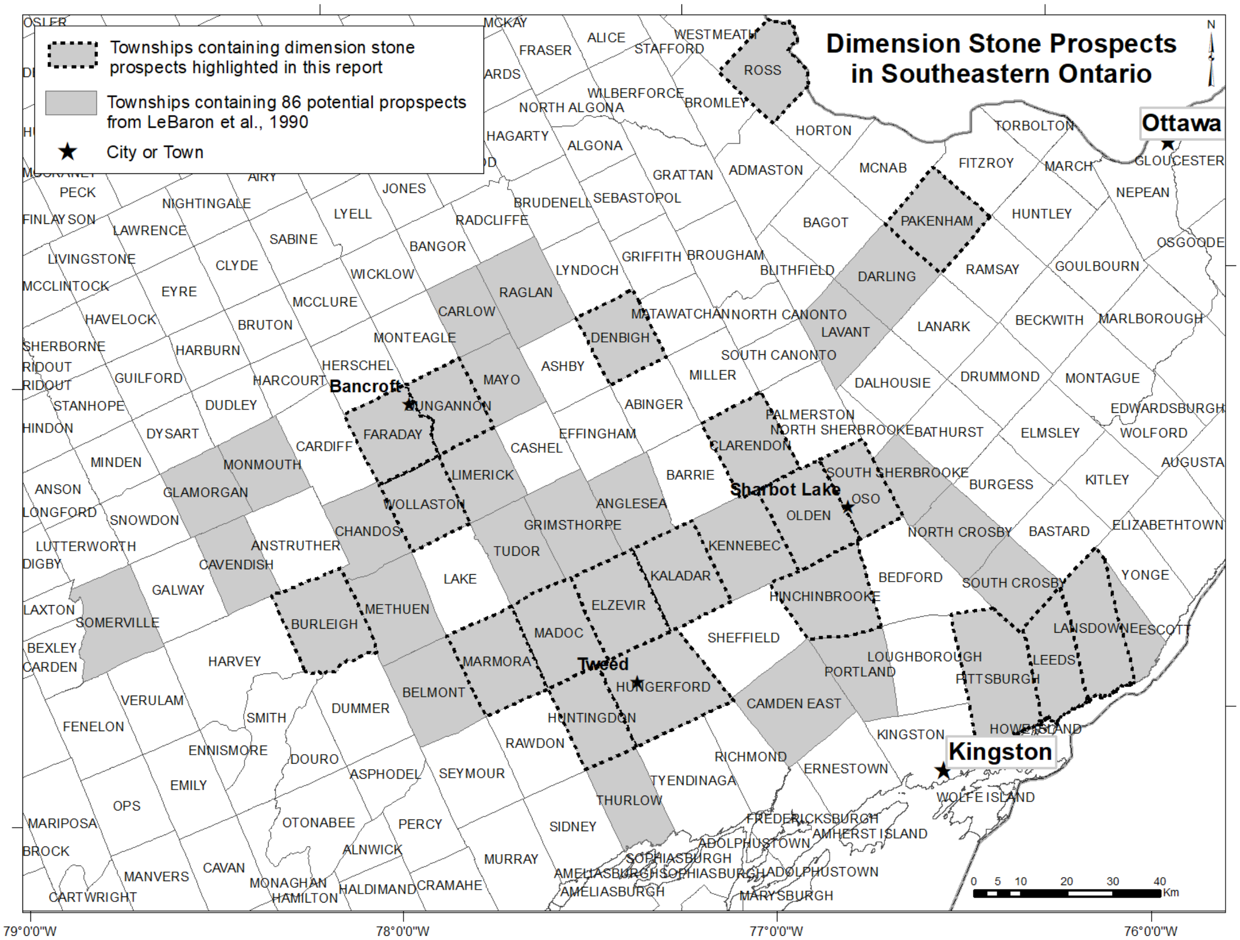


Figure 2. Township map of eastern Ontario indicating townships LeBaron et al., investigated in 1990 (grey shading). The prospects highlighted in this report are in the townships outlined with dotted lines.

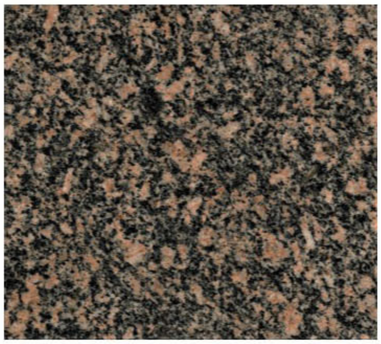
Beautiful Building Stones

The following samples (Photos 1 and 2) represent a snapshot of the dimension stone potential in southern Ontario. Details on the two hundred-plus prospects, including the samples in Photos 1 and 2, are provided in LeBaron et al (1990). These and other samples are stored and available for viewing at the Tweed office.

Most of the granite samples in Photo 1 display consistent colours and texture. Though samples 85BUR01, 86-OLD-025, 86-HIN-001 and 86-FLL-005 have variable grain size, the patterns are consistent giving these rocks a unique appearance.

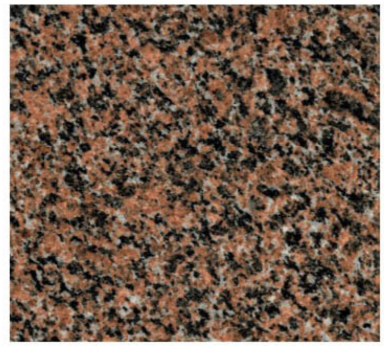
Except for 85-PAK-001 and 85-MAR-003 (*see* Photo 2), the marble and conglomerate samples in this report were chosen because they exhibit various grain sizes mixed with linear features and narrow veins cutting across the samples, features traditionally not accepted by the dimension stone industry. However, in the twenty-first century, these features are desired by architects and designers as they give the rocks an exceptional and dynamic appearance (https://blog.allplan.com/en/natural-stone).

As with the 3 granite samples, these unconventional marble and conglomerate samples display the complexity and imperfect perfection of southeastern Ontario geology. The thought of finding beauty in Nature's



85-BUR-01 Red Granite Burleigh Twp.

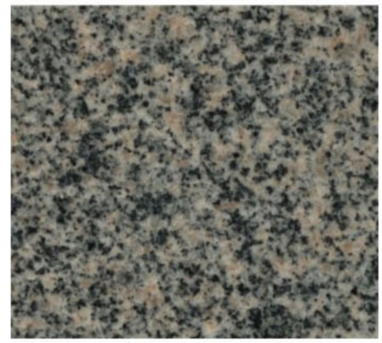
86-MAD-010 Red Granite Madoc Twp.



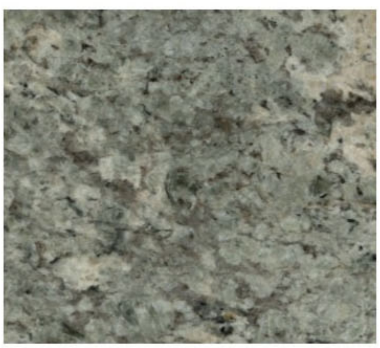
85-STO-001 Red Granite Storrington Twp.

85-RLL-001 Rideau Red Granite Rear Leeds & Lansdowne Twp.

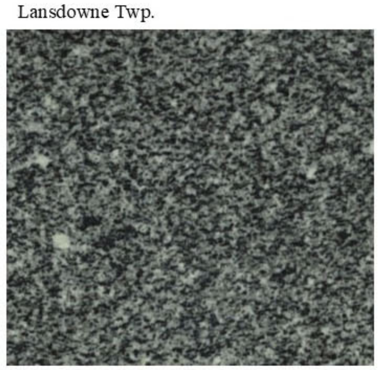
85-RLL-008 Red Granite Rear of Leeds & Lansdowne Twp.



85-WOL-001 Quartz Syenite Wollaston Twp.

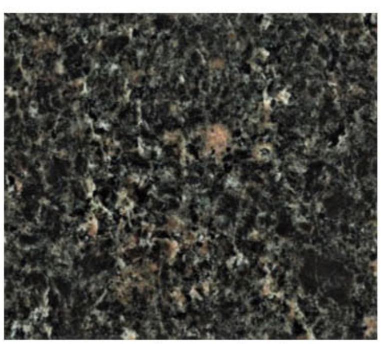


86-OLD-025 Pegmatite Olden Twp.



86-ELZ-004 Granite Elzevir Twp.

85-RLL-004 Quartz Diorite Rear of Leeds & Lansdowne Twp.



86-FLL-005 Syenite Front of Leeds & Lansdowne Twp.

86-HIN-001 Anorthosite Hinchinbrooke Twp.

85-WOL-002 Diabase Wollaston Twp.

Photo 1. A small selection of the types of granites found in southern Ontario. Photos by L. Mancini, 2020.

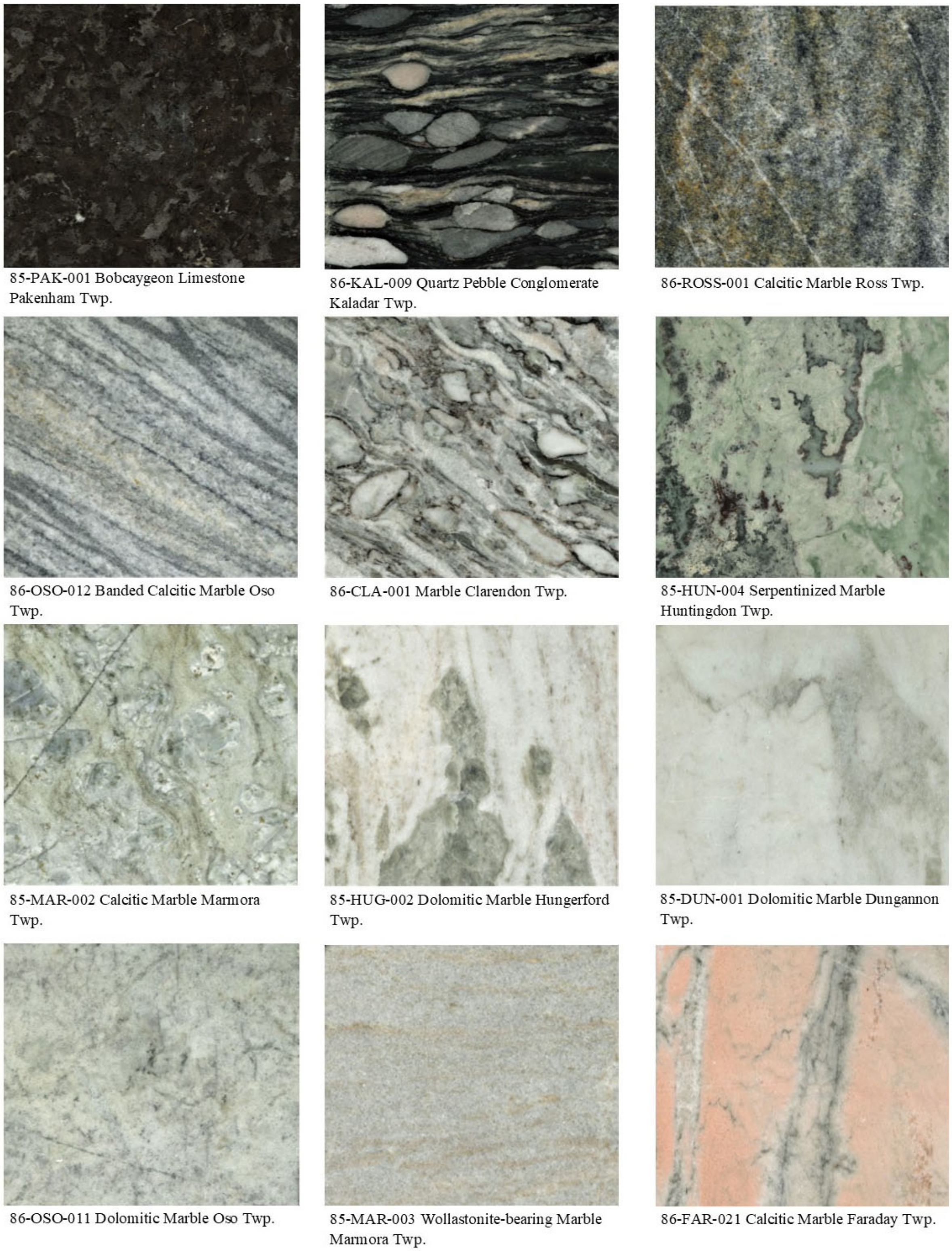


Photo 2. A small selection of marbles and other sedimentary rocks found in southern Ontario. Photos by L. Mancini, 2020.

imperfection comes from the Japanese view of Wabi-sabi which, is seeing every aspect of Nature as pure and perfect (https://www.kyoto-ryokan-sakura.com/archives/191). The samples shown in this study demonstrate this raw, natural, perfect beauty. If marketed as such, these 24, plus the rest of the 86 natural stone prospects have the potential to do very well in the growing natural stone market.

More Potential—Other Natural Stone Products

Although the more than 114 other southeastern Ontario prospects evaluated in 1990 may not have received high ratings at the time, they still warrant further exploration for the myriad of other natural stone products currently on the market. An example is stone wool insulation (another green building material) made from rocks such as diabase and basalt, stone dust, aggregates, plus many more products. One new product is a very thin stone veneer, 0.2 mm to 10 mm thick, with a carbon fiber backing that can be used on facades, furniture, and as bath and shower screening (https://www.balkepartner.com/products). The manufacturing of this product may not require 12 t to 65 t blocks traditionally quarried by the natural stone industry. The thin stone veneer may be more suited to southern Ontario deposits that are characterized by irregular or excessive jointing.

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Notes

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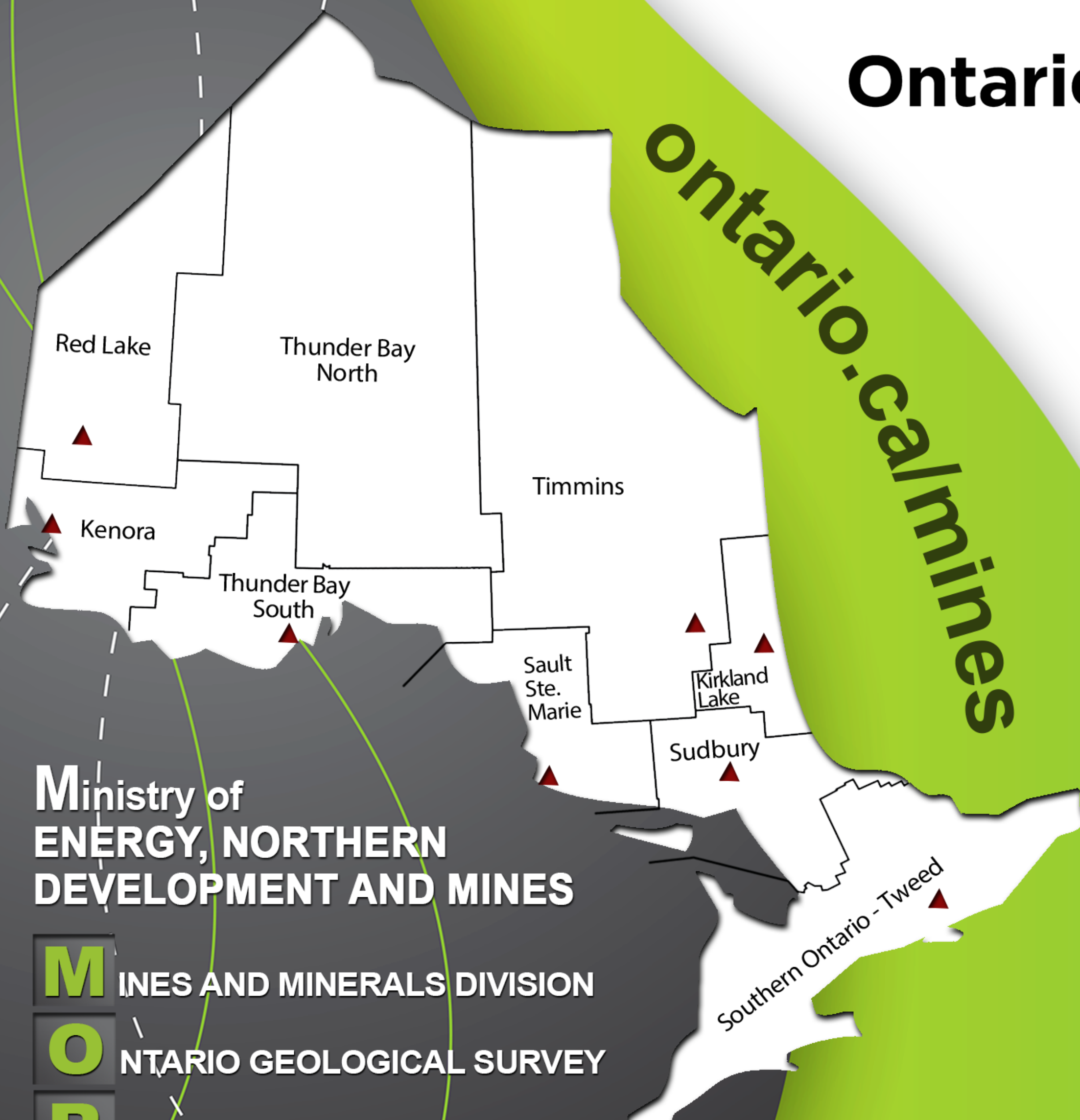

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