RECOMMENDATIONS FOR EXPLORATION 2022–2023

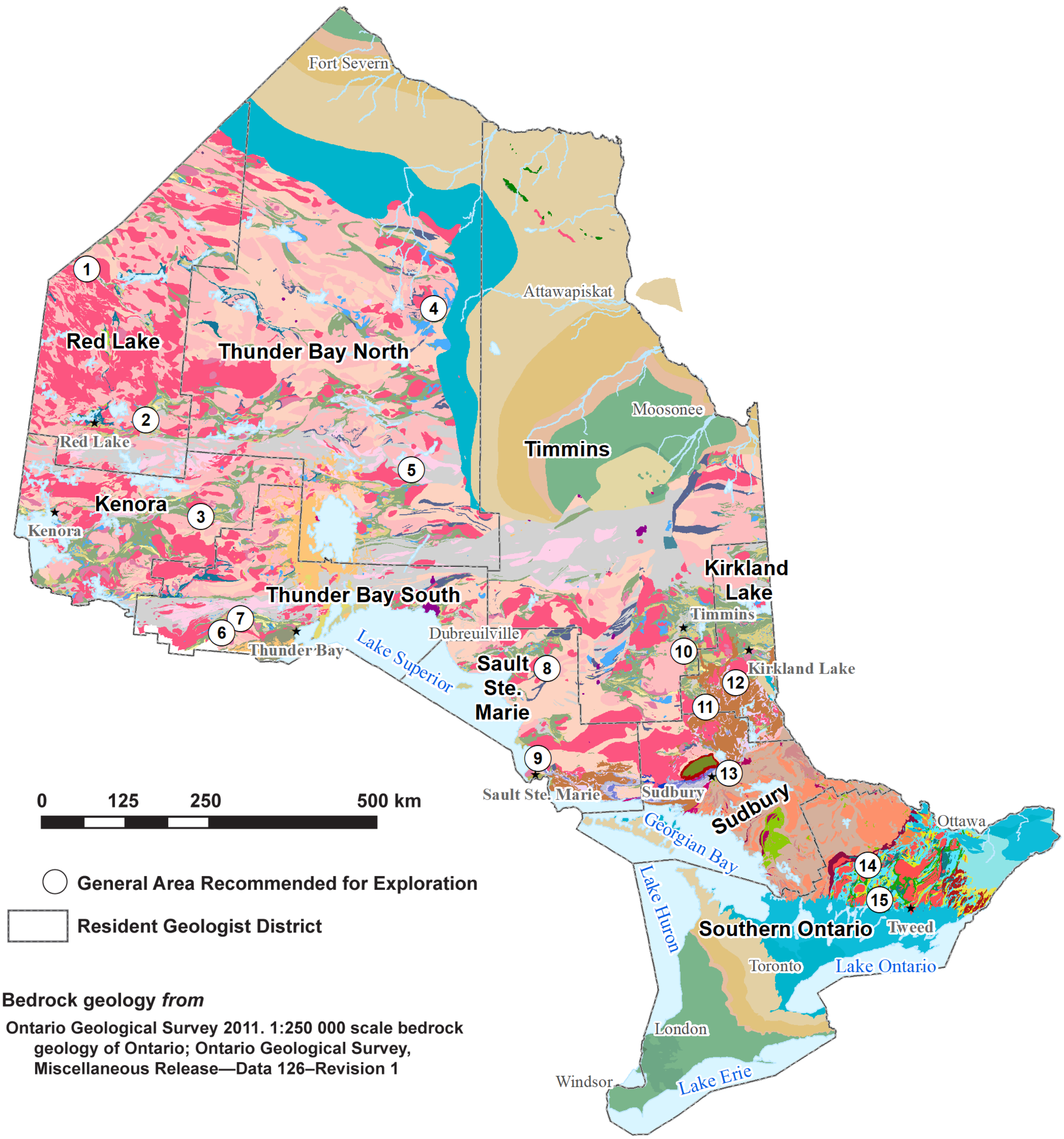
MINISTRY OF MINES

Ontario Geological Survey
Resident Geologist Program

Ontario

ONTARIO CANADA

Recommendations for Exploration 2022–2023



General Area Recommended for Exploration

Resident Geologist District

Bedrock geology *from*

Ontario Geological Survey 2011. 1:250 000 scale bedrock geology of Ontario; Ontario Geological Survey, Miscellaneous Release—Data 126–Revision 1

Ontario Geological Survey
Resident Geologist Program
Recommendations for Exploration 2022–2023

The Ontario Geological Survey (OGS) is pleased to issue its 2022–23 Recommendations for Exploration. These recommendations are the product of the dedicated and knowledgeable staff located in the 8 Resident Geologist Program (RGP) offices across the province. They have been developed using existing OGS geological and exploration data, along with new information derived from the current year's activities.

In March 2022, Ontario released its first Critical Minerals Strategy, *Ontario's Critical Minerals Strategy 2022–2027: Unlocking potential to drive economic recovery and prosperity* (https://www.ontario.ca/page/ontarios-critical-minerals-strategy-2022-2027-unlocking-potential-drive-economic-recovery-prosperity). One of the goals of this strategy is to attract increased investment in critical minerals exploration. In support of this goal, many of this year's recommendations focus on critical minerals exploration potential. Critical minerals can be defined as economically important commodities that have specific industrial, technological and strategic applications for which there are few viable substitutions. They are also at higher supply risk because of geopolitical considerations and market demand. As evidenced by this year's recommendations, Ontario's diverse geology provides excellent opportunities for the discovery and future development of new critical mineral deposits.

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

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

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About the Resident Geologist Program

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

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

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

Our services include

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

We provide geoscience information to support

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

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

For more information about the Resident Geologist Program please visit the Mines and Minerals Division Web site at www.mndm.gov.on.ca/en/mines-and-minerals/geology#simple-table-of-contents-2.

Published January 2023

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

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

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

Kurcinka, C.E. 2023. Lithium-cesium-tantalum pegmatite exploration potential along possible continuation of the Bear Head fault, Favourable Lake greenstone belt; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2022–2023, p.1-4.

HIGHLIGHTS

- **Identification of the potential western continuation of Bear Head fault (which hosts multiple lithium deposits) along the contact between the Berens River and Sachigo subprovinces**
- **Discretionary tantalite-columbite occurrence has recently been highlighted on the Manitoba side of the equivalent greenstone belt, suggesting possible fractionation**
- **Ground is open for acquisition at the time of writing**

Lithium-Cesium-Tantalum Pegmatite Exploration Potential Along Possible Continuation of the Bear Head Fault, Favourable Lake Greenstone Belt

Lithium plays a critical role in batteries produced for electric vehicles, which are continually increasing in popularity. Lithium-cesium-tantalum (LCT) pegmatites are associated with peraluminous granite plutons and are often found associated with deep faults and subprovince boundaries (Selway, Breaks and Tindle 2005). There are many areas along subprovince boundaries that have yet to be explored for a variety of critical minerals, including lithium, particularly those located in remote northern regions.

The Favourable Lake greenstone belt is located 200 km north of Red Lake, along the boundary between the Berens River subprovince to the south and the Sachigo subprovince to the north (Card and Ciesielski 1986). The Bear Head fault in the Favourable Lake greenstone belt has been explored in the eastern portion of the belt for lithium and uranium and contains the Spark and Pakeagama (PAK) lithium pegmatites (Ontario Geological Survey 2022). Currently, the PAK lithium deposit has a measured and indicated open pit resource of 5.9 Mt @ 1.81% Li_2O and an inferred resource of 680 500 t @ 1.75% Li_2O (McCracken et al. 2021), while the Spark deposit contains an indicated resource of 14.4 Mt @ 1.4% Li_2O and an inferred resource of 18.1 Mt @ 1.37% Li_2O (www.frontierlithium.com, news release, March 1, 2022). The eastern part of the Favourable Lake greenstone belt was the subject of a previous Recommendations for Exploration article on lithium-bearing rare metal pegmatites (Lichtblau 2018). The portion of the belt west of the mapped Bear Head fault has received limited exploration and contains only 1 assessment file and 2 Ontario Mineral Inventory (OMI) occurrences (Table 1; Figure 1).

The western portion of the Favourable Lake greenstone belt has undergone limited reconnaissance-scale mapping and no detailed mapping (Stone 1998a). The greenstone belt portion of this area comprises the Azure and Setting Net metasedimentary assemblages. The Azure assemblage occurs to the north and consists of conglomerate with lenses of mafic to intermediate tuffaceous flows. The grain size becomes

Table 1. Documented OMI occurrences in the Western Favourable Lake greenstone belt. Data *from* Ontario Geological Survey (2022).

OMI Identifier	Deposit Name	Deposit Status	Primary Commodity
MDI53E01SW00004	Orlac Reed Lake Mines	Occurrence	gold, lead, silver
MDI000000000417	Cochram Lake	Occurrence	molybdenum, copper

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Kurcinka, C.E. 2023. Lithium-cesium-tantalum pegmatite exploration potential along possible continuation of the Bear Head fault, Favourable Lake greenstone belt; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2022–2023, p.1-4.

finer towards the Manitoba border. The Setting Net assemblage occurs to the south and consists of clastic sedimentary rocks with mafic to ultramafic volcanic rocks and marble (Stone 1998a, 1998b). The sedimentary units are sandwiched between a biotite tonalite on both the north and south sides, followed by the Varveclay batholith to the north and the Warrington batholith to the south.

Ontario Geological Survey helicopter-borne electromagnetic (EM) and magnetic survey Geophysical Data Set 1085 and Maps M82 919 to M82 949 (Ontario Geological Survey 2018a-g) cover the entire Favourable Lake greenstone belt. Stone (1998a) suggests the Bear Head fault terminates where the Bear Head batholith intrudes the Favourable Lake greenstone belt (*see* Figure 1), although the geophysical signature attributed to the Bear Head fault appears to continue further to the west along the same trend (Figure 2). This could potentially represent a previously unmapped continuation of the fault.

Recent updates to the Mineral Deposits Database in Manitoba (Rinne 2021) have brought attention to a tantalite, columbite, tourmaline and molybdenite discretionary occurrence noted by Quinn (1960) in the Cobham River–Gorman Lake greenstone belt (equivalent to the Favourable Lake greenstone belt) across the Manitoba border. This occurrence was also noted by Derry and Mackenzie (1931). Tantalite and columbite are rare elements that are present in pegmatites at increased levels of fractionation from a granitic melt (Selway, Breaks and Tindle 2005). The occurrence of tantalite and columbite in the Cobham River–Gorman Lake greenstone belt in Manitoba suggests an increasing fractionation in the area. While there are no discrete "peraluminous" granites mapped in the immediate vicinity of both the recommended area and the Manitoba tantalite occurrence, two-mica granites have been mapped along the Bear Head fault to the east (Stone 1998b).

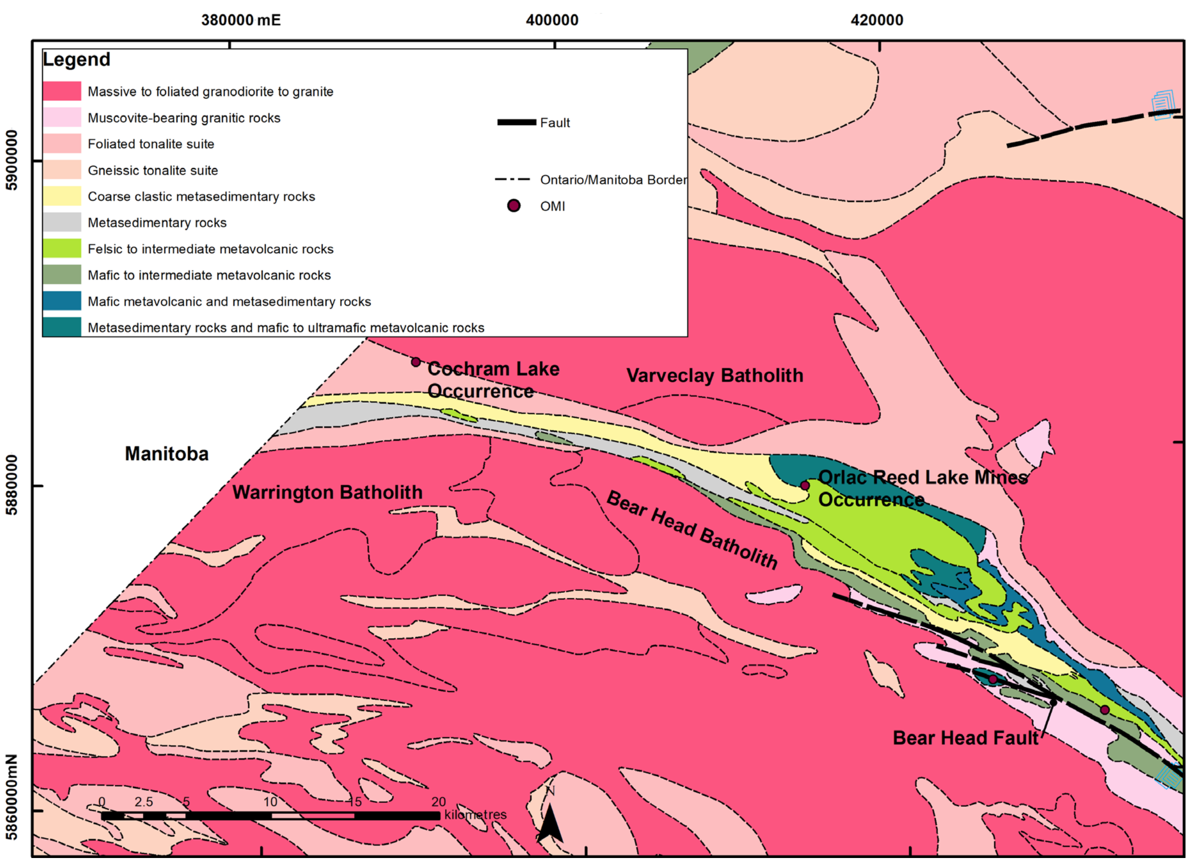

Figure 1. Geology of the western portion of the Favourable Lake greenstone belt (*modified from* Ontario Geological Survey 2011). The Bear Head fault is thought to end where the Bear Head batholith begins to impinge directly on the belt. Universal Transverse Mercator (UTM) co-ordinates in North American Datum 1983 (NAD83), Zone 15.

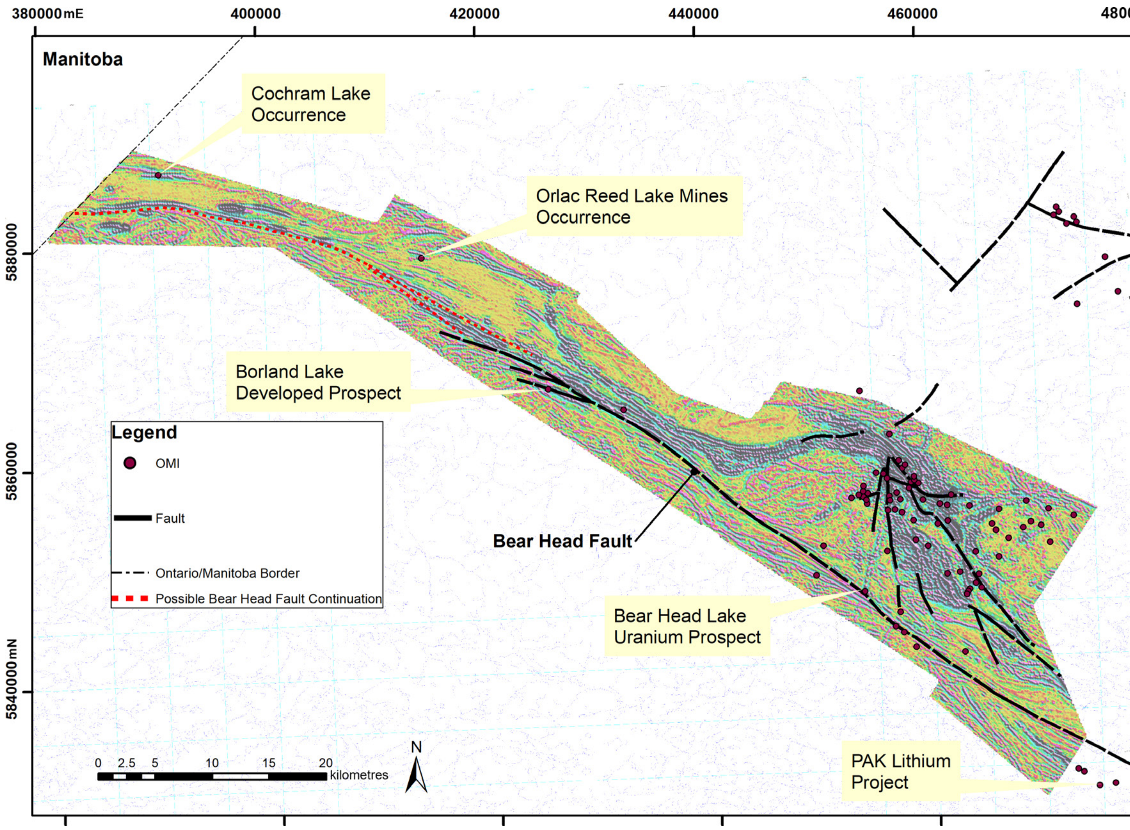

Figure 2. The second vertical derivative of the residual magnetic field in the Favourable Lake greenstone belt (*modified from* Ontario Geological Survey 2018a, 2018b), with the mapped Bear Head fault shown as black dashed lines. The geophysical survey highlights the potential continuation (red dashed line) of the Bear Head fault further to the west of its current terminus. Universal Transverse Mercator (UTM) co-ordinates in North American Datum 1983 (NAD83), Zone 15.

The western portion of the Favourable Lake greenstone belt warrants more exploration for LCT pegmatites as it represents an underexplored area along the same subprovince boundary as the Spark and PAK lithium pegmatites. If the Bear Head fault does continue into this area, it may represent a deep crustal fault along a subprovince boundary, which can be an ideal location for LCT pegmatite exploration. The presence of a nearby tantalum and columbite discretionary occurrence in Manitoba supports the potential for a more highly fractionated melt and the concentration of incompatible elements.

At the time of writing, there were no active claims in the proposed area.

References

Card, K.D. and Ciesielski, A. 1986. DNAG#1. Subdivisions of the Superior Province of the Canadian Shield; Geoscience Canada, v.13, no.1, p.5-13.

Derry, D.R. and Mackenzie, G.S. 1931. Geology of the Ontario–Manitoba boundary (12th base line to latitude 54); Ontario Department of Mines, Annual Report, v.40, pt.2, p.14-19.

Lichtblau, A. 2018. Rare metal-bearing pegmatites along the Bear Head fault; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2017–2018, p.96-97.

McCracken, T., Canosa, J.A., Boyko, K., Wilson, S. and deGagne, R.C. 2021. PAK property, PAK, Red Lake Mining District, Ontario, Canada; NI 43-101 Technical Report prepared for Frontier Lithium Inc. by BBA Inc., filed April 14, 2021, with SEDAR®, see SEDAR Home Page, 361p. [accessed October 31, 2022]

Ontario Geological Survey 2011. 1:250 000 scale bedrock geology of Ontario; Ontario Geological Survey, Miscellaneous Release—Data 126–Revision 1.

——— 2018a. Ontario airborne geophysical surveys, magnetic and electromagnetic data, grid and profile data (ASCII format) and vector data, Sandy Lake–Favourable Lake area; Ontario Geological Survey, Geophysical Data Set 1085a.

——— 2018b. Ontario airborne geophysical surveys, magnetic and electromagnetic data, grid and profile data (Geosoft® format) and vector data, Sandy Lake–Favourable Lake area; Ontario Geological Survey, Geophysical Data Set 1085b.

——— 2018c. Airborne magnetic and electromagnetic surveys, residual magnetic field contours with electromagnetic anomalies and Keating coefficients, Sandy Lake–Favourable Lake area; Ontario Geological Survey, Maps 82 919 to 82 933, scale 1:20 000.

——— 2018d. Airborne magnetic and electromagnetic surveys, colour-filled contours of the residual magnetic field and electromagnetic anomalies, Sandy Lake–Favourable Lake area; Ontario Geological Survey, Maps 82 934 to 82 937, scale 1:50 000.

——— 2018e. Airborne magnetic and electromagnetic surveys, shaded colour image of the second vertical derivative of the residual magnetic field and Keating coefficients, Sandy Lake–Favourable Lake area; Ontario Geological Survey, Maps 82 938 to 82 941, scale 1:50 000.

——— 2018f. Airborne magnetic and electromagnetic surveys, colour-filled contours of the EM decay constant and electromagnetic anomalies, Sandy Lake–Favourable Lake area; Ontario Geological Survey, Maps 82 942 to 82 945, scale 1:50 000.

——— 2018g. Airborne magnetic and electromagnetic surveys, colour-filled contours of the apparent conductivity and electromagnetic anomalies, Sandy Lake–Favourable Lake area; Ontario Geological Survey, Maps 82 946 to 82 949, scale 1:50 000.

——— 2022. Ontario Mineral Inventory; Ontario Geological Survey, Ontario Mineral Inventory, online database.

Quinn, H.A. 1960. Island Lake, Manitoba–Ontario; Geological Survey of Canada, Map 26-1960, scale 1:253 440.

Rinne, M.L. 2021. Updates to the Manitoba Mineral Deposits Database, east-central and northwestern Manitoba (NTS 53E, F, 64J, K, N, O); *in* Report of Activities 2021, Manitoba Agriculture and Resource Development, Manitoba Geological Survey, p.1-7.

Selway, J.B., Breaks, F.W. and Tindle, A.G. 2005. A review of rare-element (Li-Cs-Ta) pegmatite exploration techniques for the Superior Province, Canada, and large worldwide tantalum deposits; Exploration and Mining Geology, v.14, no.1-4, p.1-30.

Stone, D. 1998a. Precambrian geology of the Berens River area, northwest Ontario; Ontario Geological Survey, Open File Report 5963, 116p.

——— 1998b. Precambrian geology, Deer Lake area; Ontario Geological Survey, Preliminary Map P.3381, scale 1:250 000.

HIGHLIGHTS

- **Potential for germanium and indium by-product credits**
- **Critical mineral potential within the Confederation and Trout Bay assemblages**
- **50 zinc occurrences within the Red Lake and Birch–Uchi greenstone belts**

Zinc with a Splash of Germanium and Indium in the Red Lake District

Critical minerals continue to be a main focus of the exploration and mining industry in Ontario and Canada. While the Red Lake District is historically renowned for its gold endowment, there is potential for deposits hosting significant critical minerals. This Recommendation for Exploration will focus on zinc deposits and occurrences within the Red Lake and Birch–Uchi greenstone belts and their potential to host value-added germanium and indium. Not only is zinc an important critical mineral, but germanium and indium are, as well, because of their specific technical applications and the challenges in using alternative materials. Throughout the Red Lake District, there are multiple zinc occurrences identified in the Ontario Mineral Inventory (OMI) (*see* Figure 1 and Table 1). In particular, this article will examine data collected from both the South Bay Mine and High Grade Lake at the Trout Bay property, with samples collected from both.

Zinc Occurrences in the Red Lake District

Most known zinc occurrences in the Birch–Uchi and Red Lake greenstone belts are located within the Confederation assemblage (*see* Figure 1), with sphalerite as the common zinc-bearing sulphide mineral. Rocks comprising the Confederation assemblage include mafic and felsic volcanic and felsic pyroclastic rocks formed during arc volcanism (Stott and Corfu 1991). Metavolcanic rocks in the Confederation assemblage have historically been explored for their volcanogenic massive sulphide (VMS) potential. However, despite a multitude of occurrences within the assemblage, only the South Bay Mine deposit has ever been brought into production. The Trout Bay assemblage is another location with potential for zinc mineralization. The Trout Bay assemblage is typically composed of basalt, calc-alkalic tuff, intercalated sedimentary rocks and magnetite-chert banded iron formation intruded by gabbro and ultramafic rocks produced in an extensional setting and a period of sedimentation (Zagorevski 2001). Table 1 lists known zinc occurrences within the previously mentioned assemblages.

Germanium and Indium Occurrence and Usage

During 2021, 140 000 kg of germanium and 920 tonnes of indium were produced worldwide, with China leading production for both of these critical minerals (Anderson 2022; Tolcin 2022). While Canada does currently produce germanium and indium, there is a significant opportunity to increase production, particularly in Ontario. Currently, germanium and indium are both by-products from the mining of zinc deposits, such as VMS, sedimentary exhalative (SEDEX), Mississippi Valley-type (MVT) types (Shanks et al. 2017). Grades for germanium and

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indium from sphalerite concentrate typically range from 50 to 3000 ppm and 70 to 200 ppm, respectively (Paradis 2015). Examples of producing mine grades for germanium include an average of 68 ppm from the Kipushi deposit in the Democratic Republic of Congo, and ranges from 104 to 249 ppm at the Red Dog mining district in Alaska, USA (Shanks et al. 2017), while the grade of indium recovered from zinc deposits typically is in the range from <1 to 100 ppm (Anderson 2022). What makes both germanium and indium critical minerals is that their production is explicitly tied to zinc production. More zinc production produces more germanium and indium. Conversely, when zinc production decreases with dropping commodity prices, less germanium and indium are produced.

Germanium has a range of applications which include fibre optics, infrared optics and the base layer within multijunction solar cells (Shanks et al. 2017). In 2021 the average price in the USA for germanium was US$1200/kg. Production of germanium worldwide has stayed steady at 140 000 kg, with the majority of production coming from China (95 000 kg; Tolcin 2022). While there are some substitutes for germanium, they typically impact the quality of the end-product being produced (Shanks et al. 2017).

Indium is primarily used for one application, creating the coating on the surface of flat panel displays and touchscreens, without a viable alternative readily available (Shanks et al. 2017). By the end of 2021, the average price in the USA for indium was US$220/kg. Again, like germanium China is the main producer of indium for the world, producing 530 tonnes out of the world production of 920 tonnes in 2021 (Anderson 2022).

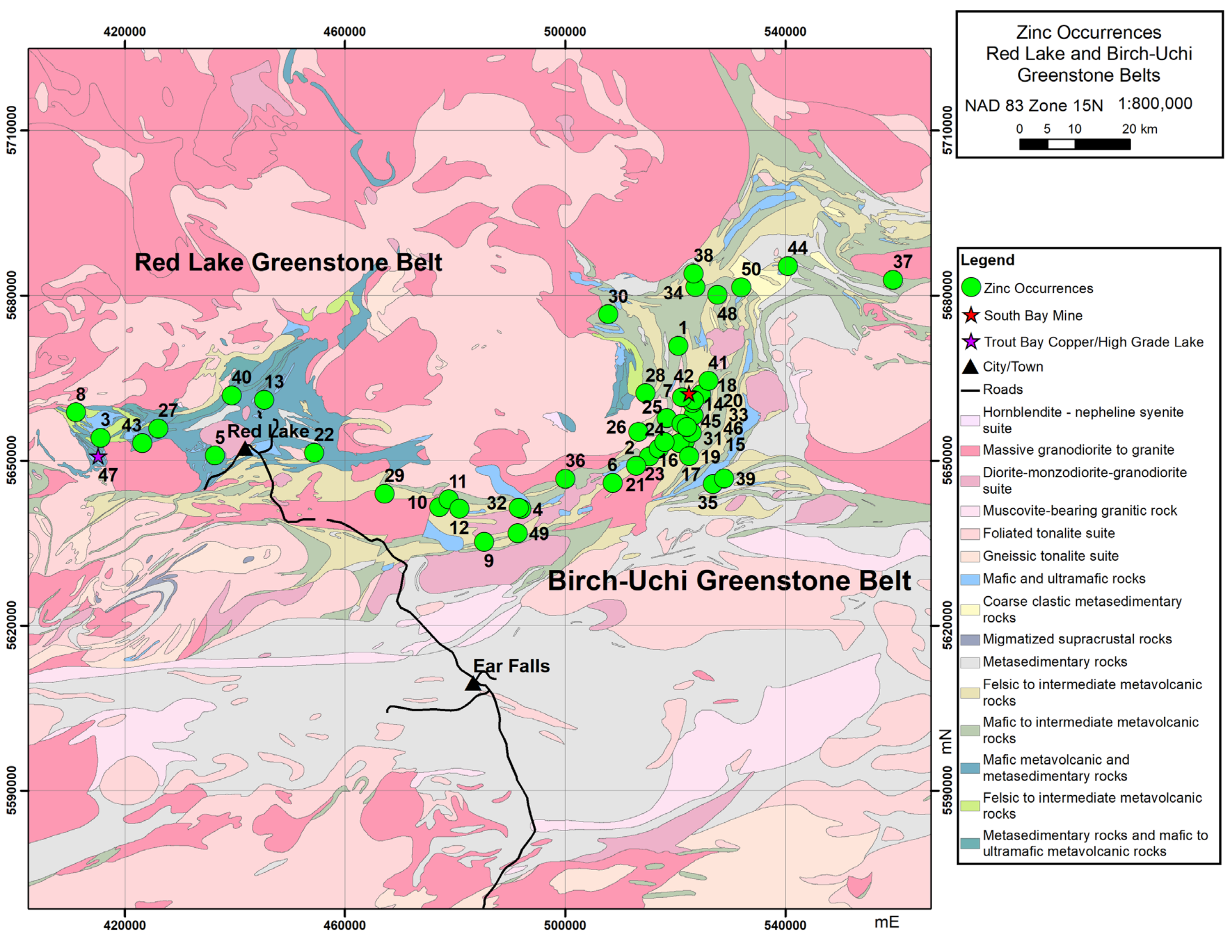

Figure 1. Location of South Bay Mine, High Grade Lake and other zinc occurrences within the Red Lake and Birch–Uchi greenstone belts; *see* Table 1 for name and location information (*modified from* Ontario Geological Survey 2011; occurrences *from* Ontario Mineral Inventory, Ontario Geological Survey 2022).

Table 1. Zinc-bearing sulphide occurrences within the Red Lake and Birch–Uchi greenstone belts (*compiled from* Ontario Geological Survey 2022). Numbers in first column keyed to Figure 1.

ID	Names	Township	Easting	Northing	Status	Commodity	Ontario Mineral Inventory (OMI)
1	Borgford Lake	Dent	520545	5670874	Occurrence Assays returned 12.9% Zn, 1.80% Cu, 0.51% Pb	Zn, Cu, Pb, Ag	MDI52N02NE00061
2	Bowerman 226-11-1,2	Bowerman	515287	5650721	Occurrence 1.88% Zn over 1.4 ft, 0.55% Zn over 1 ft	Zn	MDI52N02SW00022
3	Bridget Lake #5, W. Stupack (#5 - KRL 46184), Ball #49	Ball	415542	5654127	Occurrence 0.18% Cu, 0.05% Ni, 0.55% Zn	Zn	MDI52M01SE00228
4	Caravelle	Gerry Lake Area	492031	5641177	Occurrence 4.44% Zn and 0.22% Cu over 1.1 m	Zn	MDI52K14NE00006
5	CLS-Zn Zone	Baird	436377	5650916	Occurrence 8.75% Zn over 1 ft and 0.65% Zn over 4.5 ft	Zn	MDI52N04SW00328
6	Copper Lode “E”, Copper Lode - B,C,D,E Zones, Copper Lode Main	Belanger	508637	5645911	Developed Prospect with Reported Reserves or Resources Possible Reserves - 145 150 tonnes of 8.28% Zn	Zn, Cu, Ag	MDI52K15NW00019
7	DDH 3200-2-80	Agnew	524687	5662021	Occurrence 0.11% Cu, 1.18% Zn over 0.82 m	Zn, Cu	MDI52N02SE00072
8	Discovery Pit Zone, Biron Bay - Main Zone, Biron Bay B and C Zones, Golden Chance Partnership - Pit/Main Zone, Ledge 1	Ball	411087	5658769	Occurrence 6.39% Zn over 4 ft, 4.56% Zn over 12 inches	Zn, Au	MDI52M01SW00045
9	Dixie 3, Snake Falls property	Karas Lake Area	485250	5635223	Developed Prospect with Reported Reserves or Resources Unclassified - 91 000 tonnes of 10% Zn, 1% Cu	Zn	MDI000000000290
10	Dixie prospect - 17B	South of Otter Lake Area	477132	5641521	Prospect 6.33% Zn and 1.5% Cu over 3.35 m, 7.34% Zn and 1.44% Cu over 9.5 m	Zn, Cu	MDI52K14NW00011
11	Dixie prospect - 18	South of Otter Lake Area	478790	5642921	Developed Prospect with Reported Reserves or Resources Unclassified - 110 000 tonnes of 12.5% Zn, 0.55% Cu	Zn, Cu	MDI52K14NW00010
12	Dixie prospect - 19	South of Otter Lake Area	480807	5641268	Prospect “6.33% Zn, 1.61% Cu over 9 ft”	Zn, Cu	MDI52K14NW00012
13	East Bay - West, KRL-1516 and 1517	Dome	445279	5661029	Discretionary Occurrence Sphalerite noted	Zn	MDI52N04SW00026

Table 1. *continued*

ID	Names	Township	Easting	Northing	Status	Commodity	Ontario Mineral Inventory (OMI)
14	Fly Lake	Mitchell	523281	5658158	Occurrence "2.64% Zn over 5.4 ft"	Zn	MDI52N02SE00062
15	Fly Lake 3197-6-80	Mitchell	521532	5653085	Occurrence 7.44% Zn over 0.64 m	Zn, Pb, Cu, Ag	MDI52N02SE00077
16	Fly Lake DDH 3197-7-80	Mitchell	521764	5653487	Occurrence 3.63% Zn over 1.24 m	Zn, Pb, Ag	MDI52N02SE00078
17	Fly Lake DDH FL-90-3	Mitchell	520733	5653174	Occurrence 6.48% Zn over 0.5 m	Zn, Cu	MDI52N02SE00076
18	Fly Lake drill holes UW-40, UW-41	Mitchell	523089	5660475	Occurrence 0.23% Zn and 1.63% Cu over 0.64 m	Cu, Ag, Zn	MDI52N02SE00074
19	Fly Lake project	Bowerman	522509	5650777	Occurrence 1.84% Zn over 7.5 ft and 3.09% Zn over 0.2 m	Zn, Cu	MDI52N02SE00085
20	Fly Lake UW-36, 37	Mitchell	523405	5661001	Occurrence 1.26% over 2.3 ft and 1.28% over 1.9 ft	Zn	MDI52N02SE00073
21	Garnet Lake property - Arrow Zone, Selco	Belanger	512866	5649081	Developed Prospect with Reported Reserves or Resources Inferred Resource - 2 100 000 tonnes of 5.78% Zn and 0.72% Cu	Zn	MDI52K15NW00017
22	Hermiston zinc showing, Keg Lake - East	Byshe	454384	5651452	Occurrence 14.4% Zn and 4599, 8081, 11256 ppm Zn	Zn, Pb	MDI52N04SE00118
23	Horseshoe Lake prospect, Elbow Lake prospect	Mitchell	517003	5652197	Prospect 2.44% Zn over 5.2 ft, up to 5.5% Zn over 37 ft	Zn, Pb, Ag	MDI52N02SW00016
24	Horseshoe Lake UA-41	Mitchell	518044	5653411	Occurrence 2.79% Zn over 3 ft and 1.02% Zn over 3 ft	Zn	MDI52N02SE00075
25	Jam prospect, KRL 61479, South Bay Mines DDH U5	Mitchell	518457	5657738	Occurrence 8290 ppm Zn grab sample	Cu, Zn	MDI52N02SE00005
26	Joey prospect	Knott	513275	5655215	Discretionary Occurrence 0.48% Zn and 967 ppm Cu over 1.54 m	Zn	MDI000000001353
27	Martin Bay SW, E.M. Hall property, Cochenour Exploration Ltd.	Todd	426054	5655845	Occurrence 12.8% Zn from a grab sample	Zn, Pb, Ag, Cu	MDI52M01SE00197
28	Medicine Rock, Frank property, Gloster Option (Selco), Caribou vein	Dent	514587	5662221	Occurrence 5.46% Zn over 5 to 14 ft	Zn, Cu, Au	MDI52N02SW00020
29	Moose Creek - West, South of Otter Lake Area RLX	South of Otter Lake Area	467163	5643970	Occurrence 3.22% Zn and 0.96% Cu over 1.2 ft	Zn, Cu	MDI52K14NW00013
30	Narrow Lake North	Skinner	507802	5676585	Occurrence 0.93% Zn over 1.1 ft	Zn, Cu, Ag, Au	MDI52N02NW00036

Table 1. *continued*

ID	Names	Township	Easting	Northing	Status	Commodity	Ontario Mineral Inventory (OMI)
31	Nekapean Bay, Sulpetro DDH 3197-1-81	Mitchell	523003	5655068	Occurrence 8.25% Zn and 0.34% Cu over 1 m and 3.77% Zn over 0.3 m	Zn, Cu	MDI52N02SE00079
32	New Zone - Big Falls property, Joy Zone - Big Falls property	Gerry Lake Area	491526	5641411	Developed Prospect with Reported Reserves or Resources Inferred Resource - 300 000 tonnes over 4% Cu-Zn	Zn, Cu	MDI000000000255
33	Northern Drill Target - Nuinsco Resources	Mitchell	521221	5661513	Prospect 1.31% Zn over 1 m, 0.56% Zn over 2.4 m and 0.83% Zn over 1.5 m	Zn	MDI000000001355
34	Northwest Explorers	Shabumeni Lake Area	523641	5681545	Discretionary Occurrence 0.40% Zn, 0.05% Cu	Zn	MDI52N07SE00005
35	Panama Zn	Slate Lake Area	526851	5645728	Discretionary Occurrence 1200 ppm Zn and 270 ppm Cu over 1 m	Zn	MDI000000002286
36	Roxmark West, Roxmark "B", Queensland occurrence, Gerry Lake North	Fredart Lake Area	500045	5646689	Occurrence 2.94% Zn grab sample	Ag, Zn, Pb	MDI52K15NW00020
37	Seagrave Lake	Seagrave Lake Area	559566	5682826	Occurrence 2.68% Zn and 8.38% Zn from grab samples	Zn	MDI52N08SE00007
38	Shabumeni Lake-Pn	Shabumeni Lake Area	523320	5683985	Occurrence Drilling includes sections up to 0.83% Zn over 27.9 ft	Zn	MDI52N07SE00053
39	Slate Lake Cu-Zn-Ag	Slate Lake Area	528892	5646726	Occurrence 5.84% Zn and 1.84% Cu over 0.5 m, 8.36% Zn and 11.6% Cu over 0.25 m	Cu, Zn, Ag	MDI52K15NE00013
40	Slate Peninsula, DDH Gs-66-38	McDonough	439377	5661828	Discretionary Occurrence 0.5% Zn and 0.03% Cu over 6.2 ft	Zn, Ag	MDI52N04SW00243
41	South Bay - Crab Grid	Agnew	526032	5664470	Discretionary Occurrence 0.16% Zn over 0.9 ft and 0.22% Zn over 2.5 ft	Zn	MDI52N02NE00002
42	South Bay Mine, South Bay, Selco prospect*	Dent	522504	5662176	Past Producing Mine Without Reserves or Resources Produced: 1 637 948 tons at 11.06% Zn and 1.8% Cu	Zn, Cu, Ag	MDI52N02SE00012
43	South Wolf Bay	Todd	423113	5653149	Discretionary Occurrence 0.36% Zn grab sample	Zn, Pb	MDI52M01SE00026
44	Superstition Lake - Northwest, Loydex showing	Satterly Lake Area	540466	5685358	Discretionary Occurrence Sphalerite noted	Zn	MDI52N08SW00009

Table 1. *continued*

ID	Names	Township	Easting	Northing	Status	Commodity	Ontario Mineral Inventory (OMI)
45	Triangle Lake Northwest, Meyer Option - North Group	Mitchell	521127	5656728	Occurrence 1.18%, 1.13% and 2.29% Zn from grab samples	Zn	MDI52N02SE00081
46	Triangle Lake Southeast	Mitchell	522103	5656114	Occurrence 4.36% Zn and 0.14% Cu over 3 ft	Zn	MDI52N02SE00080
47	High Grade Lake, Trout Bay copper prospect	Mulcahy	415137	5650822	Developed Prospect with Reported Reserves or Resources "Unclassified Resources: Trout Bay Zinc Pit Zone West - 12 500 tonnes of 4.75% Zn Trout Bay Zinc Pit East - 113 180 tonnes of 7.86% Zn"	Zn, Cu, Ag	MDI52M01SE00166
48	Vanco	Honeywell	527639	5680145	Discretionary Occurrence 0.20% Zn and 0.09% Cu	Zn	MDI52N07SE00002
49	Whitefish Falls East	Gerry Lake Area	491330	5636800	Occurrence 9579 ppm Zn over 4.4 ft	Cu, Zn	MDI52K14NE00007
50	Zip Lake	Shabumeni Lake Area	532011	5681467	Occurrence 6300 ppm Zn in DDH	Zn	MDI52N07SE00073

** Lichtblau et al. (2016). Abbreviations: DDH, diamond-drill hole.*

Property Geology at South Bay Mine and High Grade Lake

The South Bay Mine is located within the Confederation assemblage of the Birch–Uchi greenstone belt, hosted within felsic metavolcanic and felsic intrusive rocks. The mine was in production from 1971 until 1981, when production ceased due to the depletion of mining reserves. Throughout the mine's 10 years of production, a total of 1 637 948 tons of ore were milled with average grades of 11.06% Zn and 1.8% Cu (Lichtblau et al. 2015).

Ore at South Bay Mine is composed of steeply dipping bodies of massive sulphides with a composition of pyrite, sphalerite, chalcopyrite and lesser amounts of pyrrhotite. The ore itself is hosted within felsic tuffs and lesser amounts of rhyolite, with pyrite masses and felsic clasts occurring within these felsic tuffs (Corkery 1977). Ore hosted within the felsic tuff has collected along the contact with the quartz feldspar porphyry (QFP) towards the east (*see* Figure 2; Lichtblau et al. 2015). The QFP is composed of both quartz and plagioclase phenocrysts that are approximately 4 to 10 mm in width (Corkery 1977). The deposit has an alteration halo around the ore body consisting of chlorite, with sericite alteration along the margins of the chlorite alteration within the QFP and felsic tuff (Lichtblau et al. 2015).

High Grade Lake (also known as the Trout Bay copper prospect) is a known zinc occurrence in the Red Lake District. High Grade Lake is hosted within the Trout Bay assemblage in the western portion of the Red Lake greenstone belt. Although High Grade Lake is a zinc and copper occurrence, the Trout Bay assemblage is also known for its nickel-copper-platinum group element (PGE) mineralization. The geology at High Grade Lake is hosted within folded argillaceous greywackes and siliceous metasedimentary rocks that occur along a contact with a gabbro sill (*see* Figure 3). Mineralization is composed primarily of a mass of sphalerite, with a halo of disseminated pyrrhotite, pyrite and chalcopyrite (Selway and Lavigne 2006).

Germanium and Indium in the Red Lake District

Throughout 2022, samples were collected and sent for analysis by staff of the Resident Geologist Program (RGP) from the Red Lake District. The 2 sites selected for sampling were the South Bay Mine and High Grade Lake because of their historical production of zinc and significance as a zinc occurrence; respectively. As mentioned previously, germanium and indium are typically found in VMS-, SEDEX- and MVT-type deposits. While the South Bay Mine is a known VMS deposit, High Grade Lake's geological model isn't well defined. High Grade Lake has been described, by Hughes (2002), as having VMS-type mineralization because of the sulphide minerals present (sphalerite, pyrrhotite, pyrite and chalcopyrite). Selway and Lavigne (2006) suggest, however, that there are multiple indicators missing to fit High Grade Lake into the VMS geological model, such as synvolcanic intrusions, semi-conformable alteration, fragmental felsic volcanic rocks and correlations between mineralization and pathfinder elements. Regardless, there is precedent to examine High Grade Lake for germanium and indium, as intercepts of 64 g/t Ge and 28.44 g/t In were reported by Hughes (2008) at High Grade Lake.

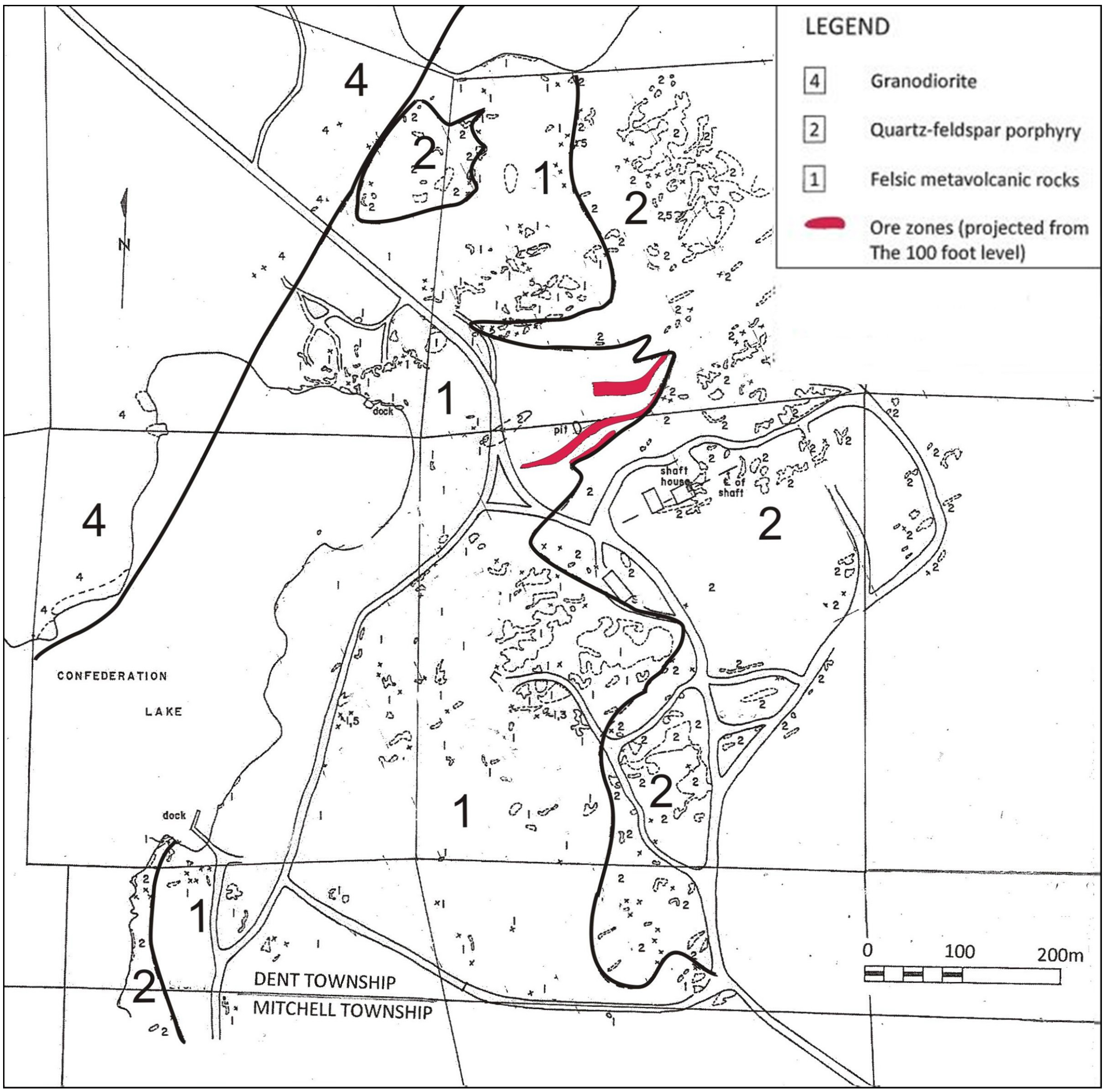

Figure 2. Surface geology of the South Bay Mine (*modified from* Lichtblau 2015).

A total of 6 samples were collected and analyzed for their germanium and indium content, with 4 samples from South Bay Mine and 2 from High Grade Lake. The samples are described in detail with their analytical results in Table 2. Although all the samples are floats or in the case of South Bay Mine, 2 samples are concentrate material, it can be assumed that all the samples are still relatively representative of mineralized material from both sites. The analysis showed that the South Bay Mine was deficient in germanium, but both the concentrate and float samples returned grades of indium up to 145 ppm, which could be of economic value when mined as a by-product alongside zinc. High Grade Lake was deficient in indium but returned anomalous values of germanium, up to 78.2 ppm.

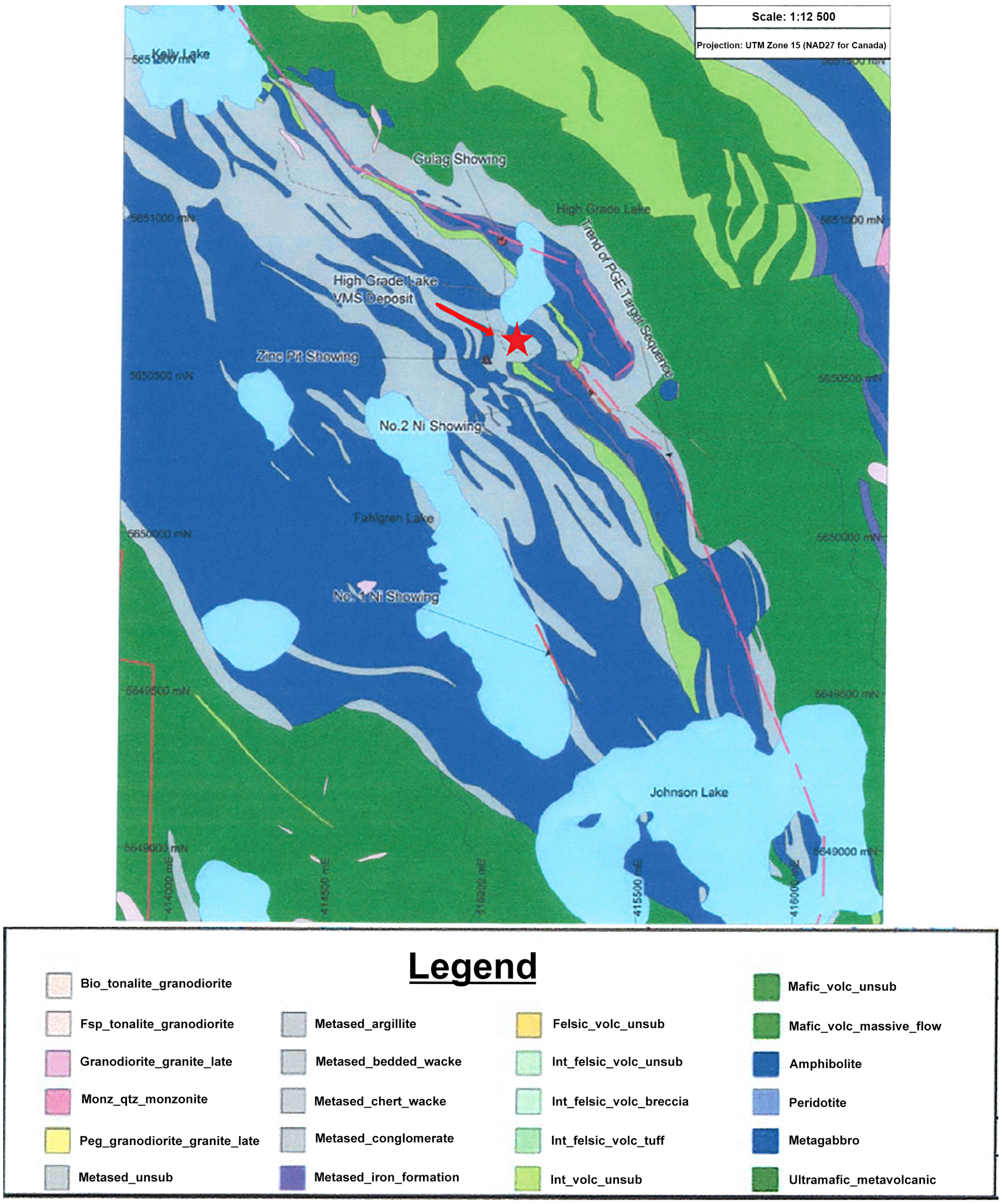

Figure 3. Property geology and location of the High Grade Lake occurrence (red star) in the Trout Bay assemblage (*modified from* Selway and Lavigne 2006).

Table 2. Description, location and results of trace element analyses* for samples collected from South Bay Mine and High Grade Lake.

Sample No.	Location	Type	Description	Ge (ppm)	In (ppm)
			Detection Limit	**0.7**	**0.2**
2022PM028	Dent Township South Bay Mine 522504E 5662176N	Concentrate	Oxidized concentrate material from the site, gravel like	3.7	99.5
2022PM029	Dent Township South Bay Mine 522504E 5662176N	Concentrate	Oxidized concentrate material from the site, gravel like	4.3	100
2022PM030	Dent Township South Bay Mine 522504E 5662176N	Float	Massive sulphide ore material, heavily oxidized. Composed of 75% chalcopyrite	5.4	111
2022PM031	Dent Township South Bay Mine 522504E 5662176N	Float	Massive sulphide, heavily oxidized. Composed of 60% pyrite, 30% chalcopyrite and 10% sphalerite	10.6	145
2022PM041	Mulcahy Township High Grade Lake 415175E 5650822N	Float	Heavily oxidized mafic (basalt?) sample from historical Zinc Pit, approximately 5% blebs of sulphide (pyrrhotite and pyrite)	78.2	1.1
2022PM042	Mulcahy Township High Grade Lake 415175E 5650822N	Float	Banded iron formation with possible bands of argillite, and massive bands of sulphide composed of pyrite, pyrrhotite and sphalerite.	44.6	14.4

**Analyses by Activation Laboratories Ltd., Ancaster, Ontario. All samples were analyzed by inductively coupled plasma optical emission spectrometry (ICP–OES) and inductively coupled plasma mass spectrometry (ICP–MS) with sodium peroxide fusion.*

Conclusion

The main goal of this article was to show that the Red Lake District has the potential for critical mineral by-products. While zinc is a critical mineral in its own right, having the added value of additional critical minerals, such as germanium and indium, is a bonus. When exploring for the next base metal deposit in the Red Lake District, it would be wise to expand the scope for exploration and complete analysis on a wider range of commodities including germanium and indium. Therefore, this recommendation for exploration is a reminder to companies and/or prospectors currently exploring or looking to acquire property in the Red Lake and Birch–Uchi greenstone belt that there may be more to your typical massive sulphide deposit in the district than meets the eye. By continuing to look outside the box when exploring for critical minerals, Ontario can expand its presence in the development and production of critical minerals, including zinc, germanium and indium.

References

Anderson, C.S. 2022. Indium; Mineral Commodity Summaries—January 2022, U.S. Geological Survey. https://www.usgs.gov/centers/national-minerals-information-center/mineral-commodity-summaries .

Corkery, M.T. 1977. A study of the geology of the sulphide ore bodies at South Bay Mines, northwestern Ontario; unpublished MSc thesis, University of Manitoba, Winnipeg, Manitoba, 97p.

Hughes, T.N.J. 2002. Executive summary, Trout Bay project, Ball, Killala and Mulcahy townships, Red Lake area, Ontario; Non-Assessment File, RL1516, 15p.

——— 2008. Report on drilling programme June–July, 2008, Trout Bay property, Red Lake, Ontario, Puget Ventures Inc.; Red Lake Resident Geologist's office, Mulcahy Township, assessment file 20000000689, 376p.

Lichtblau, A.F., Ravnaas, C., Storey, C.C., Tuomi, R.D., Tims, A., Debicki, R.L., Pettigrew, T.K., Paju, G.F. and Wetendorf, J. 2016. Report of Activities 2015, Resident Geologist Program, Red Lake Regional Resident Geologist Report: Red Lake and Kenora Districts; Ontario Geological Survey, Open File Report 6314, 130p.

Lichtblau, A.F., Ravnass, C., Storey, C.C., Tims, A., Debicki, R.L., Pettigrew, T.K., Wilson, A.C. and Wetendorf, J. 2015. Report of Activities 2014, Resident Geologist Program, Red Lake Regional Resident Geologist Report: Red Lake and Kenora Districts; Ontario Geological Survey, Open File Report 6301, 83p.

Ontario Geological Survey 2011. 1:250 000 scale bedrock geology of Ontario; Ontario Geological Survey, Miscellaneous Release—Data 126–Revision 1.

——— 2022. Ontario Mineral Inventory; Ontario Geological Survey, Ontario Mineral Inventory (September 2022 update), online database.

Paradis, S. 2015. Indium, germanium and gallium in volcanic- and sediment-hosted base-metal sulphide deposits; *in* Symposium on Strategic and Critical Materials Proceedings, November 13–14, 2015, Victoria, British Columbia, British Columbia Geological Survey Paper 2015-3, p.23-29.

Selway, J. and Lavigne, J. 2006. Independent Technical Report, Trout Bay property, Red Lake, Ontario; Non-Assessment File RL5048, 41p.

Shanks, W.C.P., III, Kimball, B.E., Tolcin, A.C. and Guberman, D.E. 2017. Germanium and indium; *in* Critical Mineral Resources of the United States – Economic and Environmental Geology and Prospects for Future Supply, U.S. Geological Survey Professional Paper 1802, p.I1-I26. https://pubs.er.usgs.gov/publication/pp1802I

Stott, G.M. and Corfu, F. 1991. Uchi subprovince; *in* Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part 1, p.145-236.

Tolcin, A.C. 2022. Germanium; Mineral Commodity Summaries—January 2022, U.S. Geological Survey. https://www.usgs.gov/centers/national-minerals-information-center/mineral-commodity-summaries .

Zagorevski, A. 2001. Tectono-metamorphic history of the Trout Bay assemblage, Red Lake, Ontario; unpublished BSc thesis, University of Ottawa, Ottawa, Ontario, 76p.

HIGHLIGHTS

- **Underexplored rocks on trend with the historical zinc, copper, lead and silver Sturgeon Lake mining camp**

South Sturgeon Assemblage Rocks Open for Acquisition

Approximately 70 km north-northeast of the town of Ignace, the Sturgeon Lake mining camp was a prolific producer of volcanogenic massive sulphide ore from 1970 to 1991, producing 19.8 million tons at an average of 8.50% Zn, 1.06% Cu, 0.91% Pb and 119.7 g/t Ag (Franklin 1996). Ore production in the Sturgeon Lake camp came from the contacts between 4 stratigraphic sequences within the Sturgeon Lake Caldera Complex (Doyle and Allen 2003). These sequences include the Pre-Caldera, Early Caldera, Late Caldera and the Lyon Lake Fault sequences (Hudak 1996; Figure 1). The largest deposit (Mattabi) is hosted by intermediate to felsic volcanic rocks of the Early Caldera and Late Caldera sequences, grouped by Sanborn-Barrie and Skulski (2005) and termed the South Sturgeon assemblage (SSA).

Figure 2 illustrates a potential western continuation of the SSA rocks host to volcanogenic massive sulphide mineralization which are here recommended for follow-up exploration. The SSA rocks may continue along a lineament that has been identified in second vertical derivative geophysical imagery and which continues beyond the western extent of the Sanborn-Barrie and Skulski (2005) map area (Figure 3). Previous exploration in the recommended area occurred *circa* 1970 (Amos 1971) and mainly consisted of geophysical surveys, where multiple anomalies were identified. Of particular interest, an anomalous magnetic response that aligns with a weak electromagnetic conductor is noted which suggests the presence of sulphides and coincides with a portion of the proposed continuation of SSA rocks (Amos 1971; Figure 3).

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Amyotte, E. 2023. South Sturgeon assemblage rocks open for acquisition; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2022–2023, p.15-18.

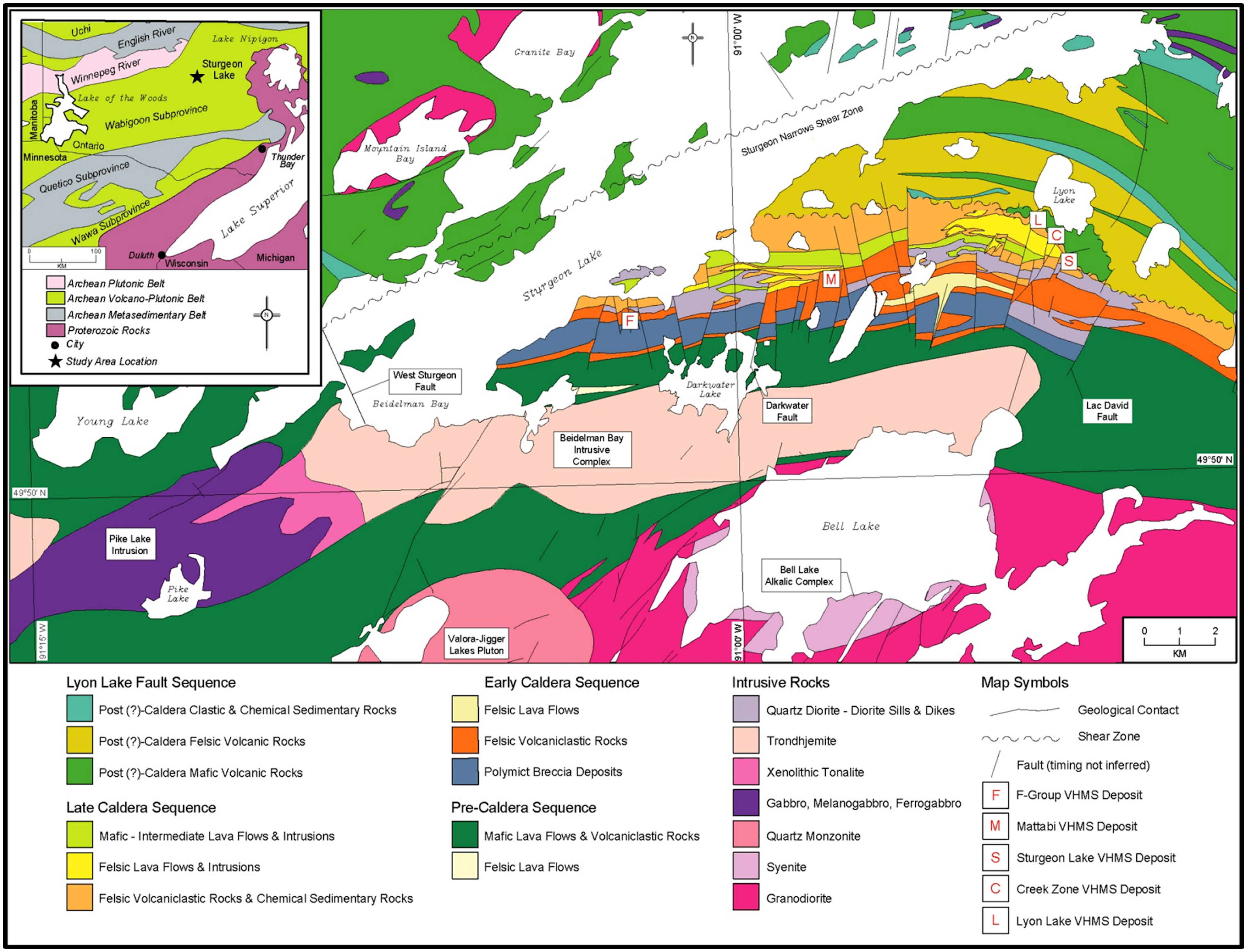

Figure 1. Geology of the Sturgeon Lake Caldera Complex (*from* Lessard and Ratthe 2020).

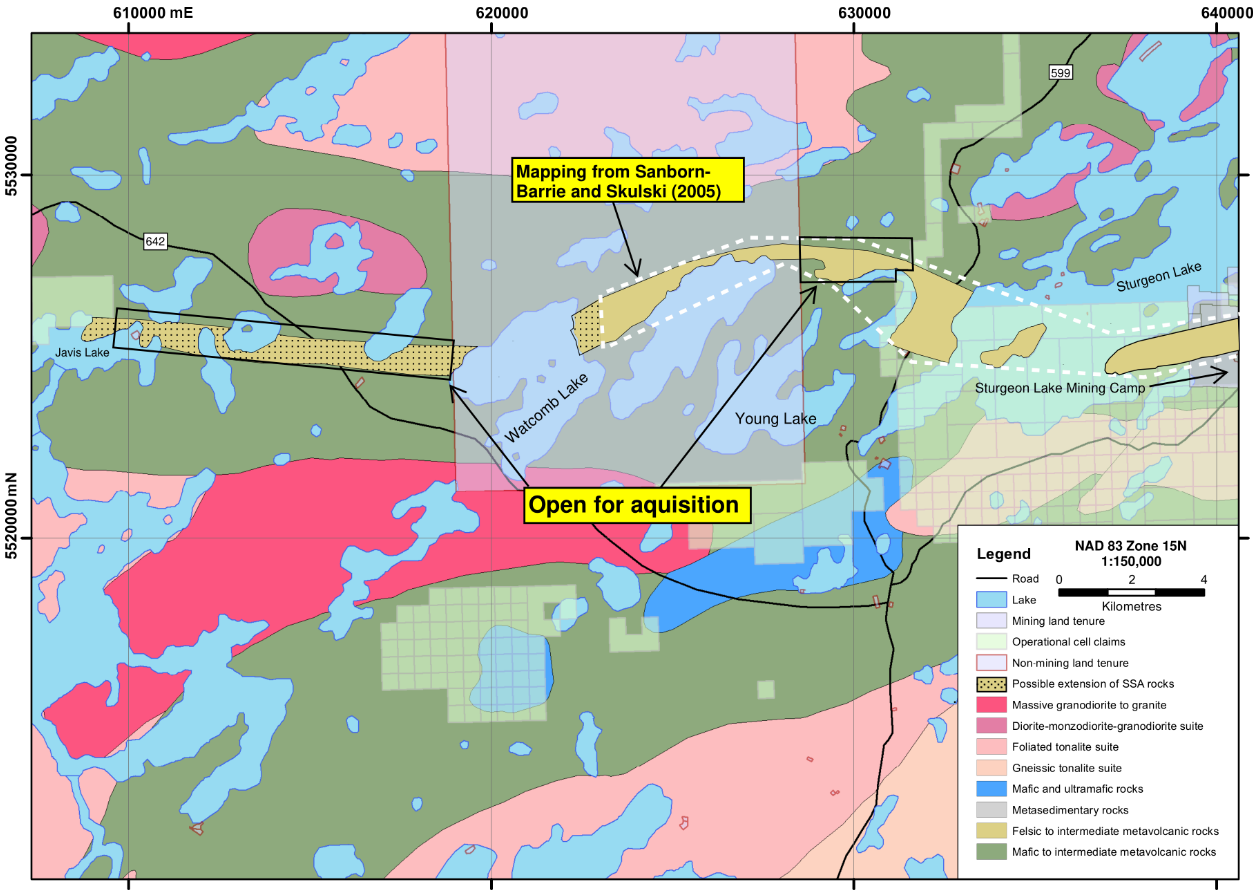

Figure 2. Simplified bedrock geology of the Sturgeon Lake greenstone belt illustrating SSA rocks open for acquisition. The felsic to intermediate metavolcanic rocks in yellow-brown were mapped by Sanborn-Barrie and Skulski (2005). The dotted yellow-brown polygon is a trace of SSA rocks which may extend beyond the western limit of Sanborn-Barrie and Skulski (2005) mapping, along a lineament identified from second vertical derivative geophysical imagery (Ontario Geological Survey 2003a, 2003b) (geology *from* Sanborn-Barrie and Skuski 2005 and Ontario Geological Survey 2011).

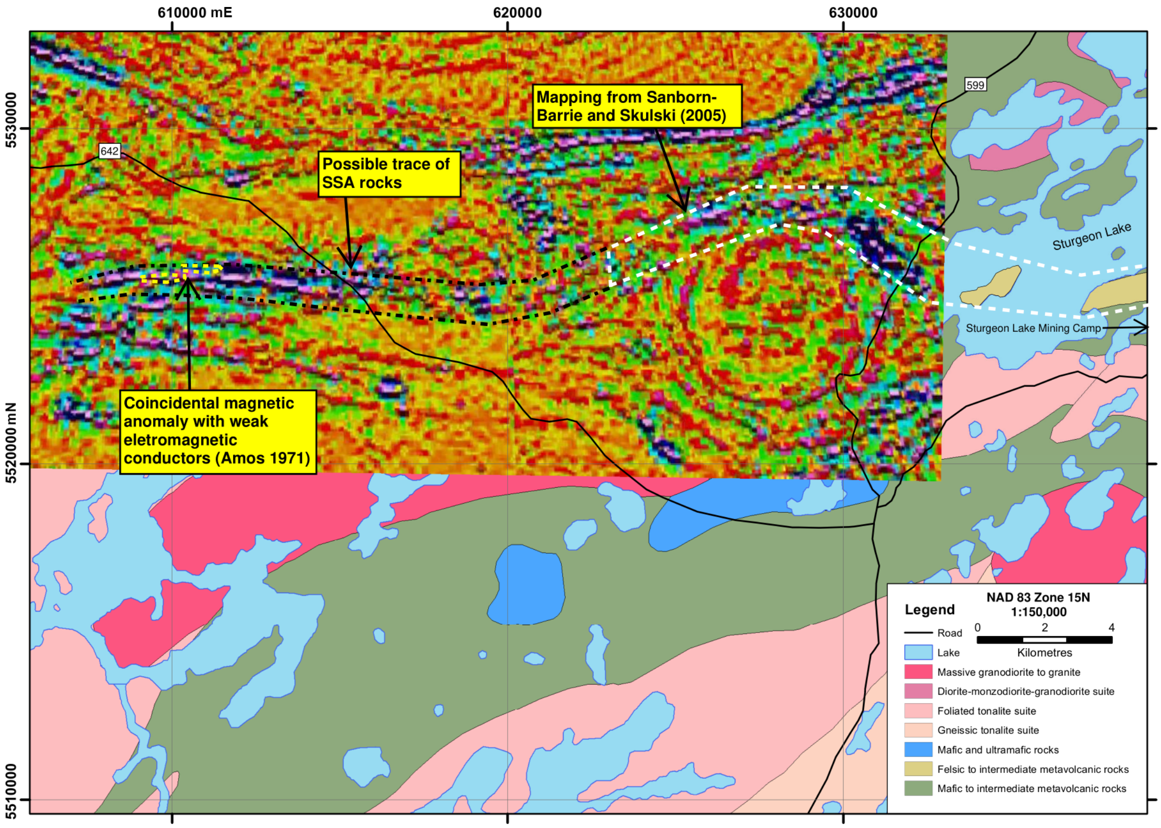

Figure 3. Simplified bedrock geology of the Sturgeon Lake greenstone belt overlain by second vertical derivative geophysical imagery, showing a possible trace of SSA rocks along the lineament within the dashed lines (black dotted and dashed line, *from* Amos 1971; geophysical imagery *from* Ontario Geological Survey 2003a, 2003b; geology *from* Ontario Geological Survey 2011). Felsic to intermediate metavolcanic rocks of the SSA mapped by Sanborn-Barrie and Skulski (2005) shown as white dashed line.

References

Amos, J.S. 1971. Geophysical surveys report for Gaspe Quebec Mines Limited, Slaght Township, Patricia Mining Portion; A.C.A. Howe International Limited, Kenora Resident Geologist's office, Press Lake area, assessment file 52G14SW0022.

Doyle, M.G. and Allen, R.L. 2003. Subsea-floor replacement in volcanic-hosted massive sulphide deposits; Ore Geology Reviews, v.23, p.183-222.

Hudak G.J. 1996. The physical volcanology and hydrothermal alteration associated with late caldera volcanic and volcaniclastic rocks and volcanogenic massive sulphide deposits in the Sturgeon Lake region of northwestern Ontario; unpublished PhD thesis, University of Minnesota, Minneapolis, Minnesota, 463p.

Franklin, J.M. 1996. Volcanic-associated massive sulphide base metals; *in* Geological Survey of Canada, Geology of Canada Series no.8, p.158-183.

Lessard P. and Ratthe, G. 2020. 2019 diamond drilling campaign report, Sturgeon Lake property, Ontario, Canada; Kenora Resident Geologist's office, GTP Block 7, assessment file 20000018459.

Ontario Geological Survey 2011. 1:250 000 scale bedrock geology of Ontario; Ontario Geological Survey, Miscellaneous Release—Data 126–Revision 1.

——— 2003a. Ontario airborne geophysical surveys, magnetic and electromagnetic data, grid and profile data, ASCII and Geosoft® formats, Sioux Lookout area; Ontario Geological Survey, Geophysical Data Set 1023.

——— 2003b. Ontario airborne geophysical surveys, magnetic and electromagnetic data, Sturgeon Lake–Savant Lake area; Ontario Geological Survey, Geophysical Data Set 1033.

Sanborn-Barrie, M. and Skulski, T. 2005. Geology, Sturgeon Lake greenstone belt, western Superior Province, Ontario; Geological Survey of Canada, Open File 1763, scale 1:100 000.

HIGHLIGHTS

- **McFaulds Lake area has seen no historical exploration for lithium-rich pegmatites or pegmatites in general**
- **Numerous lithium and cesium lake sediment anomalies**
- **No known rare earth metal or rare earth element OMI locations near lake sediment anomalies**
- **Presence of peraluminous and two-mica granites within the area**

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Ring of Fire: A Grassroots Look for Lithium

The McFaulds Lake ("Ring of Fire") region is host to numerous commodities, many of which are required to facilitate the transfer to a "Green Economy". Because of the continued demand for electric cars, mobile devices, long-term energy storage and the sustained need for the raw materials used in the creation of lithium-ion batteries (i.e., lithium, graphite, cobalt and nickel), new sources of these commodities need to be discovered. Here we highlight the Ring of Fire region and its potential for lithium, based on lake sediment anomalies.

The data presented in this article is based on lake sediment data collected by the Ontario Geological Survey (OGS) from the McFaulds Lake area (Handley and Dyer 2018) and information from the OGS Resident Geologist Program's (RGP) Ontario Mineral Inventory (OMI) online database. The sampling sites from which the raw data was collected, and the interpreted anomalies, are not proximal to any known rare earth element or rare metal occurrences in the OMI (Ontario Geological Survey 2022).

As lithium-cesium-tantalum (LCT) pegmatites are the primary target for lithium mineralization in the Superior Province, only lithium (Li) and cesium (Cs) data from deep and shallow sampling were considered in the article. Shallow sampling is defined as material collected from 0 to 15 cm into the lake bottom, whereas deep sampling is material collected from a depth greater than 20 cm into the lake bottom.

Based on the work of Hunt (2003) and Dickman and Fortescue (1991), the average sediment deposition rate is approximately 1.5 cm per decade within lakes on shield landscapes. Shallow sampling is considered to approximately represent sedimentation occurring during the past 100 years and, therefore, may be subject to anthropogenic contamination. Deep sediment sampling, on the other hand, represents sedimentation older than 100 years, thereby better reflecting the effects of natural geochemical inputs that may be traced to local geology and/or mineralization. In the case of lithium and cesium, there should be no anthropogenic input into the study area, so the geochemistry of the shallow samples should also be representative of local bedrock geology.

Proportional dot maps for lithium and cesium are plotted on a bedrock geology map (*see* Figures 1 and 2). "Anomalous" is defined for concentration values exceeding the 95th percentile of the data set for that element, while "strongly elevated" is defined for values exceeding the 90th percentile. The concentrations of all elements have been normalized to loss on ignition (LOI) during the assay process to remove any artificial anomalies generated by the effect of the organic content on the trace element concentrations.

Paju, G.F. 2023. Ring of Fire: A grassroots look for lithium; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2022–2023, p.19-23.

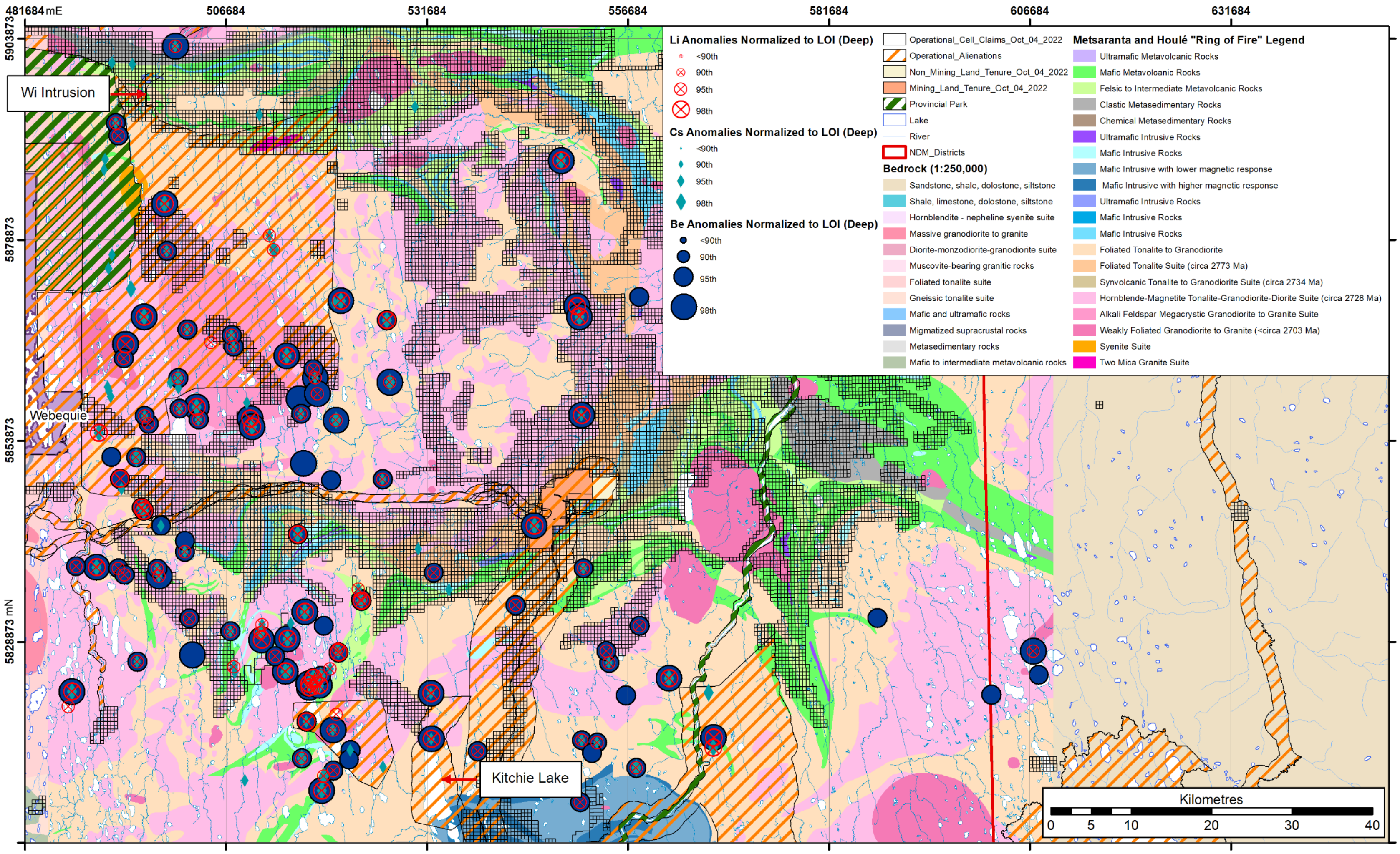

Figure 1. Deep sediment sampling lithium and cesium anomalies overlain on bedrock geology map. Geology *from* Ontario Geological Survey (2011), Metsaranta and Houlé (2017a, 2017b, 2017c); lake sediment data *from* Handley and Dyer (2018). Universal Transverse Mercator (UTM) co-ordinates in North American Datum (NAD83), Zone 16. Claim units current to October 4, 2022.

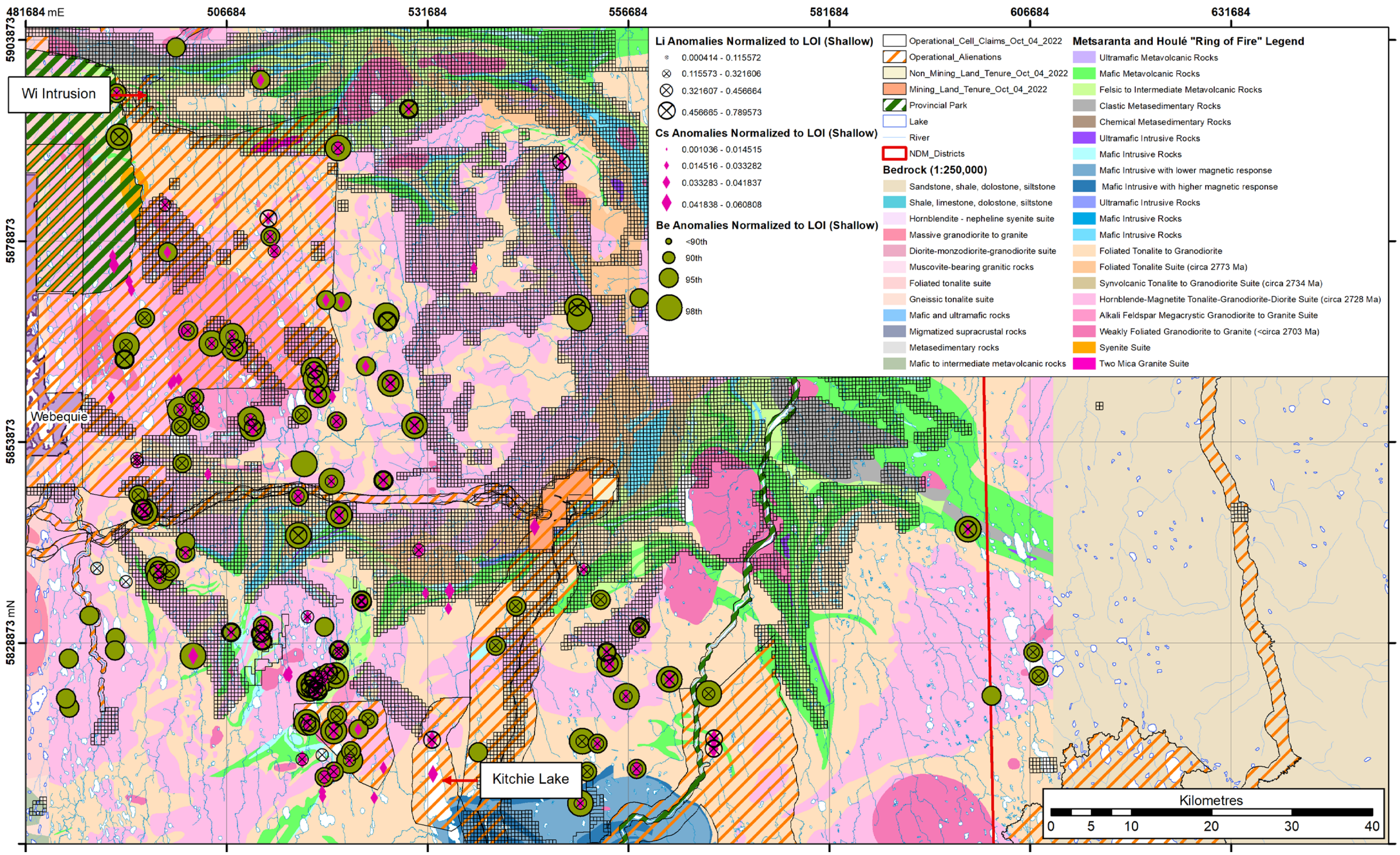

Figure 2. Shallow sediment sampling lithium and cesium anomalies overlain on bedrock geology map. Geology data *from* Ontario Geological Survey (2011), Metsaranta and Houlé (2017a, 2017b, 2017c); lake sediment data *from* Handley and Dyer (2018). Universal Transverse Mercator (UTM) co-ordinates in North American Datum (NAD83), Zone 16. Claim units current to October 4, 2022.

The deep (Figure 1) and shallow (Figure 2) sediment geochemical anomalies display a similar distribution in the Ring of Fire area, with the bulk of the anomalies occurring between Webequie First Nation and the Highbank–Fishtrap Lake intrusive complex. Despite this spread of geochemical anomalies, no LCT-type mineralization has been documented by either the OGS or the exploration industry within the Ring of Fire region.

Metsaranta and Houlé (2020) noted that within the Ring of Fire region there are volumetrically (relative to the other rock types) minor peraluminous, medium-grained biotite-muscovite-garnet granite to granite pegmatite suite (map unit 19) rocks that are generally massive to weakly foliated. These peraluminous rocks are currently only known to occur as minor sills and dikes in drill core and are rarely seen in outcrop, with one such occurrence found in a drill core from the Kitchie assemblage (<2725 Ma) near the Highbank–Fishtrap Lake intrusive complex in the southern part of the area (Metsaranta and Houlé 2020). These units have the potential to be a parental fertile granite. Buse et al. (2009) had previously mapped a small two-mica granite intrusion along the Winiskisis Channel south of the Wi intrusion (*see* Figures 1 and 2).

West of the Ring of Fire region in the southwestern portion of the Winisk Lake area, Buse et al. (2009) noted that the syenitic Wapikopa pluton (2698.7±0.8 Ma; Kamo 2008) contained pegmatitic phases with coarse-grained apatite crystals up to 6 cm long. The last phase of regional plutonism is believed to be represented by 2 separate rock types: a two-mica granite and widespread pegmatites (Buse et al. 2009).

Within the Winisk Lake area the medium-grained and locally pegmatitic two-mica granite was noted to be found only in proximity with greenstone slivers and consists of biotite, muscovite and garnet (Buse et al. 2009). Buse et al. (2009) proposed these granites likely represent a sedimentary source because of their proximity to the greenstone belts.

The pegmatite intrusions and dikes originated from a more metaluminous melt (Buse et al. 2009). The pegmatites range in composition from quartz syenite to granite with very little biotite. When present, biotite occurs as books of crystals and is commonly accompanied by graphic-textured intergrowths of potassium feldspar and quartz (Buse et al. 2009). Locally, large nodules of magnetite (2 to 3 cm in diameter) are found within these pegmatites. The pegmatites are found throughout the Winisk Lake area usually as dikes, but at the southernmost part of the area, there is a multi-kilometre-wide pegmatite intrusion (Buse et al. 2009). The pegmatites in the southern portion seem to be related to I-type plutonism within the Winisk Lake area (Buse et al. 2009).

A fertile granite is the parental granite to rare-element pegmatite dikes, which are typically distributed over a 10 to 20 km^2 area within 10 km of the fertile granite (Selway, Breaks and Tindle 2005). The granitic melt first crystallizes into several different granitic units (e.g., biotite granite to two-mica granite (previously identified within the Ring of Fire region) to muscovite granite), because of an evolving melt composition, within a single parental fertile granite pluton.

Previous OGS studies in the Ring of Fire region (cf. Gao and Crabtree 2016; Crabtree and Gleeson 2003) had uncovered rare earth element (REE) anomalies within till and alluvium samples and suggested their mineralization potential. They were unable to determine the mineralization style, but both concluded that they are related to pegmatitic rocks, highlighting the potential for rare earth element-bearing pegmatites in addition to LCT-type pegmatite mineralization. The area V from Gao and Crabtree (2016) identified anomalous concentrations of REEs (up to 194 ppm) within the till and alluvium at Kitchie Lake, indicating the potential for metaluminous granitoids as observed by Buse et al. (2009) within the Winisk Lake area. The potential for mineralization related to pegmatites is further supported by Metsaranta and Houlé (2020), who noted a peraluminous granite dike cutting the Kitchie assemblage in drill core at Kitchie Lake.

Future grassroots exploration of the McFaulds Lake area should focus on the re-sampling and re-logging of drill core to determine the presence of peraluminous fertile granites. Fertile granites can be evaluated on the basis of trace element and mineral geochemistry (cf. Selway, Breaks and Tindle 2005). Additionally, examination of potential regional zoning within the fertile granite and pegmatite units could be a useful vector toward potential

LCT pegmatites. Bulk whole-rock compositions and potassium feldspar and muscovite mineral compositions may be useful in determining the degree of fractionation of the granite and pegmatite. The reader is referred to Selway, Breaks and Tindle (2005) and references therein for background information of exploration methods for fertile granites and rare element pegmatite units.

References

Buse, S., Smar, L., Stott, G.M. and McIlraith, S.J. 2009. Precambrian geology of the Winisk Lake area; Ontario Geological Survey, Preliminary Map P.3607, scale 1:100 000.

Crabtree, D.C. and Gleeson, C.F. 2003. Results of the "Spider 3" regional kimberlite indicator mineral and geochemistry survey carried out in the vicinity of the upper Attawapiskat and Ekwan rivers, northern Ontario; Ontario Geological Survey, Open File Report 6097, 127p.

Dickman, M. and Fortescue, J. 1991. The role of lake deacidification as inferred from sediment core diatom stratigraphies; AMBIO – A Journal of the Human Environment, v.20, no.3-4, p.129-135.

Gao, C. and Crabtree, D.C. 2016. Results of regional till and modern alluvium sampling in the McFaulds Lake ("Ring of Fire") area, northern Ontario; Ontario Geological Survey, Open File Report 6309, 164p.

Handley, L.A. and Dyer, R.D. 2018. McFaulds Lake ("Ring of Fire") area lake sediment and water geochemistry, northern Ontario; Ontario Geological Survey, Miscellaneous Release—Data 373.

Hunt, C. 2003. Metal concentrations and algal microfossil diversity in pre-industrial (pre-1880) sediment of lakes located on the Sudbury Igneous Complex in Sudbury, Ontario; unpublished MSc thesis, Laurentian University, Sudbury, Ontario, 124p.

Kamo, S.L. 2008. U-Pb ID–TIMS ages of rocks from the Webequie map area, northwestern Ontario [for the Ontario Geological Survey]; unpublished report of the Jack Satterly Geochronology Laboratory, Department of Geology, University of Toronto, Earth Sciences Centre, 22 Russell Street, Toronto, Ontario, M5S 3B1, 7p.

Metsaranta, R.T. and Houlé, M.G. 2017a. Precambrian geology of the Winiskisis Channel area, "Ring of Fire" region, Ontario—Northern sheet; Ontario Geological Survey, Preliminary Map P.3804; Geological Survey of Canada, Open File 8200, scale 1:100 000. https://doi.org/10.4095/299708

——— 2017b. Precambrian geology of the McFaulds Lake area, "Ring of Fire" region, Ontario—Central sheet; Ontario Geological Survey, Preliminary Map P.3805; Geological Survey of Canada, Open File 8201, scale 1:100 000. https://doi.org/10.4095/299711

——— 2017c. Precambrian geology of the Highbank Lake area, "Ring of Fire" region, Ontario—Southern sheet; Ontario Geological Survey, Preliminary Map P.3806; scale 1:100 000. https://doi.org/10.4095/299712

——— 2020. Precambrian geology of the McFaulds Lake "Ring of Fire" region, northern Ontario; Ontario Geological Survey, Open File Report 6359, 260p.

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

———— 2022. Ontario Mineral Inventory; Ontario Geological Survey, Ontario Mineral Inventory, online database.

Selway, J.B., Breaks, F.W. and Tindle, A.G. 2005. A review of rare-element (Li-Cs-Ta) pegmatite exploration techniques for the Superior Province, Canada, and large worldwide tantalum deposits; Canadian Institute of Mining, Metallurgy and Petroleum, Exploration and Mining Geology, v.14, no.1-4, p.1-30.

HIGHLIGHTS

- **Understudied metasedimentary–plutonic basin with potential for hosting fertile granites and rare-element pegmatites**
- **Previous drilling has uncovered an area for grassroots rare-element pegmatite potential**

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Rare-Element Pegmatite Potential in the Eastern English River Subprovince

The English River Subprovince (ERS) is one of two metasedimentary-dominated subprovinces within the Superior Province in Ontario (Breaks 1991). Along with the Quetico Subprovince to the south, these 2 basinal, metasedimentary-dominated subprovinces are known to host peraluminous, S-type fertile granites (Breaks, Selway and Tindle 2003). Given the known linkage between S-type granites and rare-element pegmatites (cf. Breaks and Moore 1992; Breaks, Selway and Tindle 2003; Selway, Breaks and Tindle 2005), the understudied east-central English River Subprovince has potential to host unknown rare-element mineralization.

The ERS is subdivided into 2 major domains: the northern supracrustal domain and the southern plutonic domain. The southern domain consists of mainly granitic intrusive rocks, and the northern supracrustal domain, which forms the northern two-thirds of the ERS, is dominated by wacke-pelite rocks that have been partially melted to form migmatites and S-type granites (Breaks and Bond 1993). By volume, metasedimentary rocks and their migmatite derivatives constitute approximately 60% of the ERS (Breaks 1991). These rocks are host to abundant batholiths, stocks, and other intrusive bodies, including a suite of peraluminous granite-granodiorite bodies that have ages from 2668 to 2692 Ma and were generated during Abukama-type regional anatexis (Breaks 1991; Breaks, Selway and Tindle 2003).

Previous studies of the ERS have largely focused on the western extent of the belt (e.g., Breaks and Bond 1993; Hrabi and Cruden 2006), while the eastern extent to the east of Armstrong (UTM Zone 16U E355066) is still poorly understood. Exploration has been recommended along the northern and southern boundaries of the subprovince, and these areas are known to host abundant rare-element mineralization (e.g., Linklater Lake and Superb Lake pegmatites (Breaks, Selway and Tindle 2002, 2003)). However, the interior of the eastern ERS deserves further investigation. The Quetico Subprovince hosts mineralized rare-element pegmatites across its extent, with a large percentage located within the centre of the subprovince (Pye 1965; Breaks, Selway and Tindle 2003). The ERS is geologically similar to the Quetico Subprovince (Breaks 1991) and, as such, has the potential to host rare-element pegmatites within its interior. The lack of exploration activity completed in the area, as well as minimal detailed mapping, limits our understanding of the mineral potential of the ERS. The lack of work in the ERS is largely due to limited road access in the area and poor outcrop exposure. Citing the evidence above, the eastern-central ERS represents an understudied and underexplored area with high potential to host undiscovered rare-element-bearing pegmatites. Large portions of the eastern ERS are open for acquisition at the time of publication.

Kurucz, S.V. 2023. Rare-element pegmatite potential in the eastern English River Subprovince; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2022–2023, p.24-27.

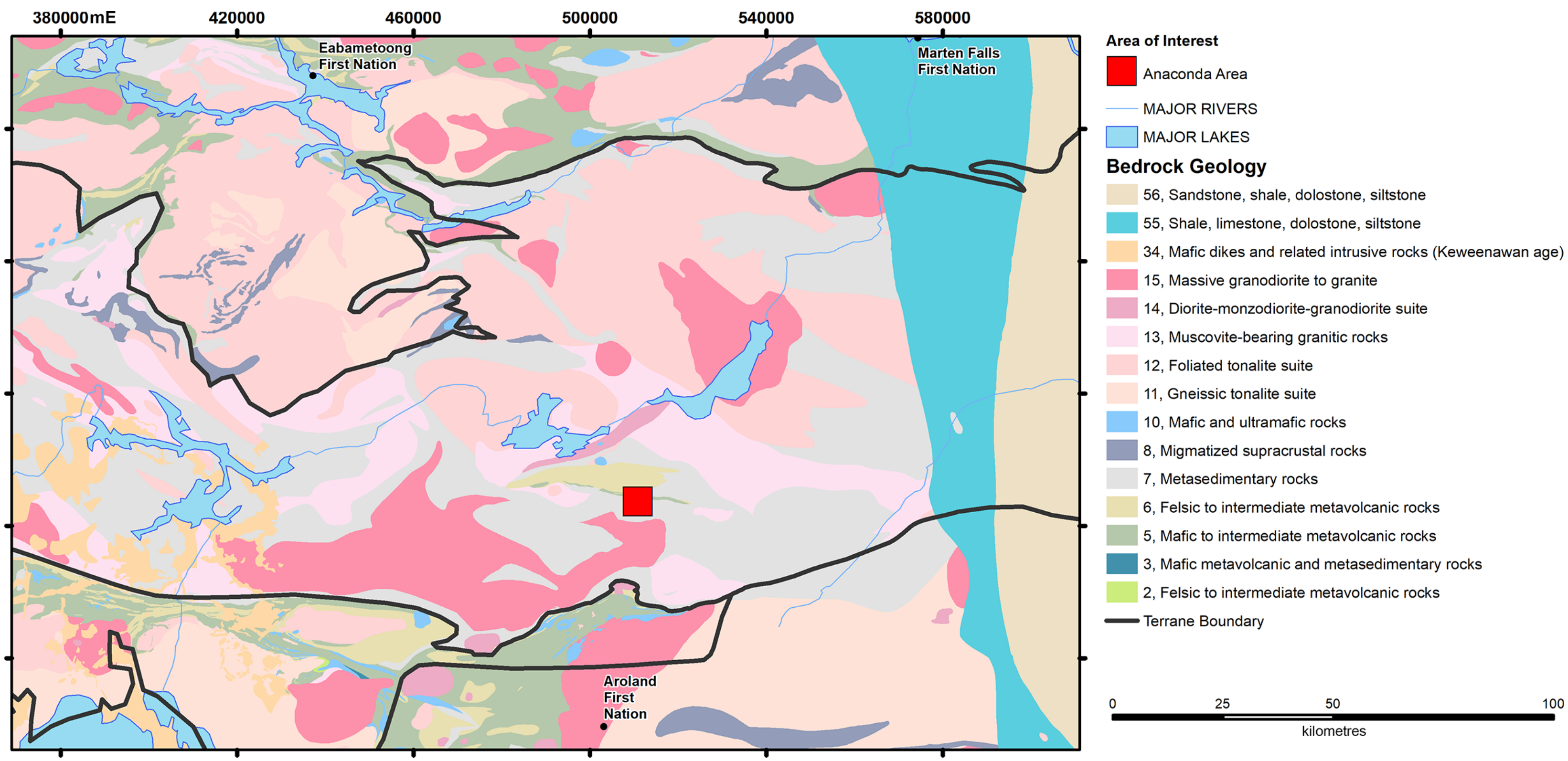

Figure 1. General geological map of the eastern English River Subprovince. Red box (Anaconda iron mine area) indicates area of recommendation for exploration. Geology *from* Ontario Geological Survey (2011). Universal Transverse Mercator (UTM) co-ordinates in North American Datum 1983 (NAD83), Zone 16.

One specific area of the eastern ERS recommended for exploration is the Anaconda iron mine area (Figure 1). The Anaconda area is proximal to the southern boundary of the ERS and has been subject to exploration and drilling for iron. Historical exploration in this area has not focused on rare-element pegmatites thus recommended areas are based on the limited information that is currently available.

Diamond drilling in 1994 in the vicinity of the Anaconda iron mine, Durer Lake area, by Jilbey Exporation Ltd. (Norwin Geological Limited 1994) led to the intersection of numerous pegmatites, several of which are described in drill logs as bearing muscovite and/or garnet along with other mineralogical indicators of rare-element fertility (cf. Selway, Breaks and Tindle 2005). Figure 2 shows locations of drill holes drilled outside of mining leases that have encountered pegmatites described as bearing muscovite and/or garnet. Additionally, drill holes D-94-01 (green circle) and D-94-03 (yellow circle) encountered pegmatite described as containing an unidentified green-blue mineral. Many blue and green minerals are described from rare-element pegmatites, including muscovite, tourmaline, fluorapatite and beryl (Selway, Breaks and Tindle 2005). The Aldor Exploration beryl occurrence (*see* Figure 2; Ontario Mineral Inventory MDI42L10NW00012, Ontario Geological Survey 2022) occurs proximal to this area, which further strengthens this area as having potential for rare-element pegmatites. The presence of pegmatites with mineralogy suggestive of rare-element potential indicates that the area in and around the Anaconda iron mine leases is a promising location for further investigation.

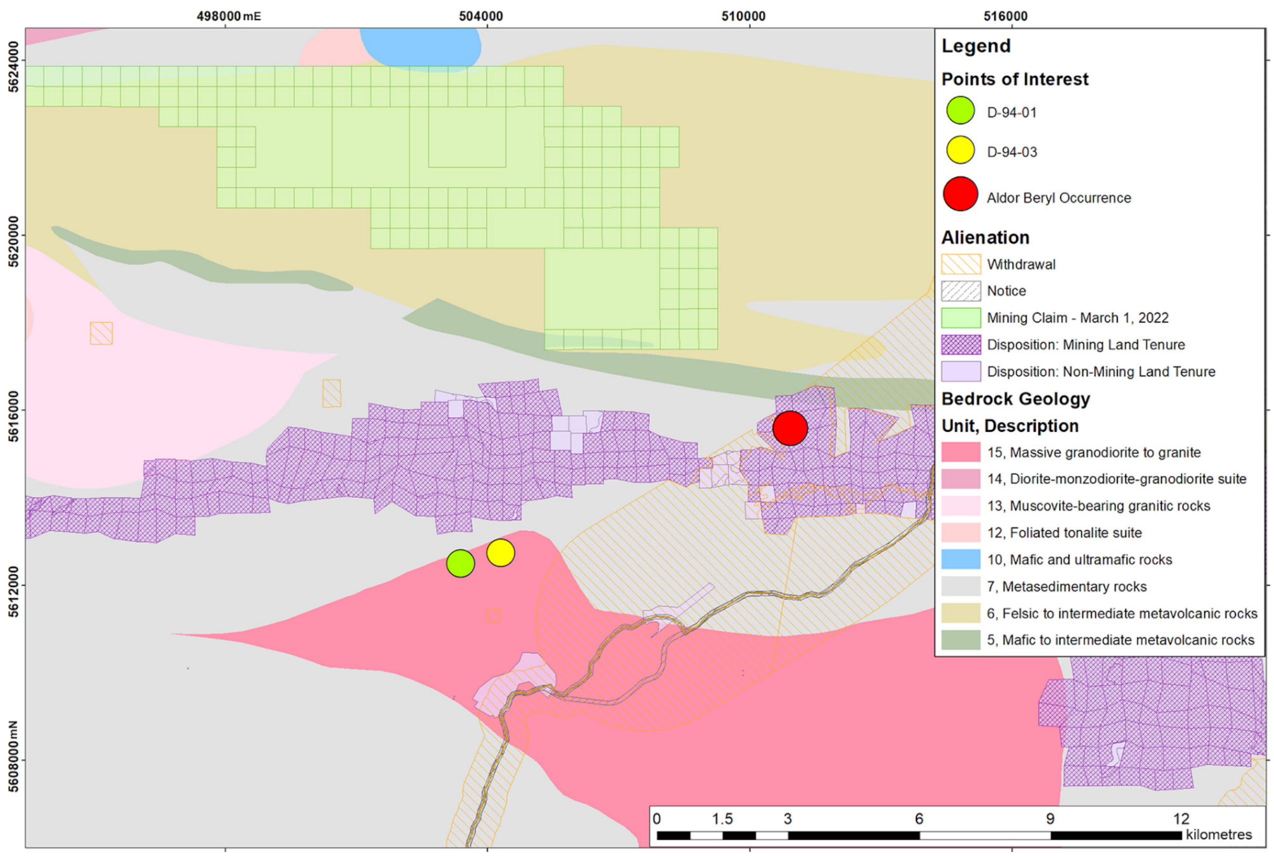

Figure 2. Map showing the locations of the drill holes (green and yellow dots) in the Anaconda area that intersected pegmatites with noteworthy mineralogy as well as their proximity to the Aldor beryl occurrence. Geology *from* Ontario Geological Survey (2011). Universal Transverse Mercator (UTM) co-ordinates in North American Datum 1983 (NAD83), Zone 16.

References

Breaks, F.W. 1991. English River Subprovince; *in* Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part 1, p.239-277.

Breaks, F.W. and Bond, W.D. 1993. The English River Subprovince – An Archean gneiss belt: Geology, geochemistry and associated mineralization; Ontario Geological Survey, Open File Report 5846, v.1, p.1-483, 884p.

Breaks, F.W. and Moore, J.M., Jr. 1992. The Ghost Lake batholith, Superior Province of northwestern Ontario: A fertile, S-type, peraluminous granite-rare-element pegmatite system; The Canadian Mineralogist, v.30, p.835-875.

Breaks, F.W., Selway, J.B. and Tindle, A.G. 2002. Fertile and peraluminous granites and related rare-element pegmatite mineralization, Superior Province, northeastern Ontario; *in* Summary of Field Work and Other Activities, 2002, Ontario Geological Survey, Open File Report 6100, p.6-1 to 6-42.

——— 2003. Fertile peraluminous granites and related rare-element mineralization in pegmatites, Superior Province, northwest and northeast Ontario: Operation Treasure Hunt; Ontario Geological Survey, Open File Report 6099, 179p.

Hrabi, R.B. and Cruden, A.R. 2006. Structure of the Archean English River Subprovince: Implications for the tectonic evolution of the western Superior Province, Canada; Canadian Journal of Earth Sciences., v.43, p.947-966.

Norwin Geological Limited 1994. Diamond drill logs, Durer Lake property; unpublished drill logs, Norwin Geological Limited, 27p.

Ontario Geological Survey 2011. 1:250 000 scale bedrock geology of Ontario; Ontario Geological Survey, Miscellaneous Release—Data 126–Revision 1.

——— 2022. Ontario Mineral Inventory; Ontario Geological Survey, Ontario Mineral Inventory, online database.

Pye, E.G. 1965. Geology and lithium deposits of the Georgia Lake area, District of Thunder Bay; Ontario Department of Mines, Report 31, 113p.

Selway, J.B, Breaks, F.W. and Tindle, A.G. 2005. A review of rare-element (Li-Cs-Ta) pegmatite exploration techniques for the Superior Province, Canada, and large worldwide tantalum deposits; Exploration and Mining Geology, v.14, no.1-4, p.1-30.

HIGHLIGHTS

- **Archean mafic-ultramafic intrusions in the Northern Light Lake area are underexplored, prospective nickel-copper-PGE exploration targets**
- **Elevated metal values discovered via prospecting and drilling, coupled with anomalous lake sediment and till data and geophysical anomalies**
- **Potential exists for discovery of mineralized mafic-ultramafic rocks associated with sanukitoid Icarus pluton**
- **This area may also be prospective for nickel-copper-PGE mineralization associated with the Midcontinent Rift**

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Nickel-Copper-PGE Potential in Archean Intrusions of the Northern Light Lake Area

Several mafic-ultramafic intrusions in the Northern Light Lake area represent underexplored and prospective targets for nickel-copper-platinum group element (Ni-Cu-PGE) mineralization. These intrusions can be recognized by their strong, positive magnetic response, several of which are coincident with areas of high conductivity and multi-element lake sediment anomalies. Limited historical prospecting has identified anomalous copper (Cu), nickel (Ni), palladium (Pd), platinum (Pt), +/- gold (Au), zinc (Zn) in some of these intrusions.

Additionally, potential exists for the discovery of mafic-ultramafic rocks associated with the Icarus pluton, which is coincident with lake sediment, till and stream sediment anomalies.

The Northern Light Lake area has been subject to minimal historical exploration, with only select areas covered by detailed mapping and geophysical surveys. The recommended area is almost completely open for staking at the time of this publication (Figure 1).

Geological Setting and Exploration History

The Northern Light–Perching Gull Lakes batholithic complex is a granitoid-dominated portion of the Wawa Subprovince, bound by the Shebandowan and Saganagons greenstone belts to the north and overlain by Proterozoic sedimentary rocks of the Animikie Group to the southeast (Williams et al. 1991). Several diorite-monzodiorite-syenite intrusions within this batholithic complex contain members of the mantle-derived "sanukitoid suite". The sanukitoid suite comprises felsic to intermediate intrusive rocks that are enriched in large ion lithophile elements (LILEs) and contain higher levels of Ni, magnesium (Mg) and chromium (Cr) compared to nonsanukitoid intrusive rocks of similar composition (Stern, Hanson and Shirey 1989). Syntectonic to posttectonic sanukitoid suite intrusions are prospective settings in which to explore for Ni-Cu-PGE-bearing Neoarchean mafic-ultramafic rocks in northwestern Ontario (Smyk et al. 2002). The Lac des Iles complex, Roaring River complex and the Entwine Lake complex are examples from northwestern Ontario in which Ni-Cu-PGE-mineralized mafic-ultramafic rocks are genetically and spatially related to sanukitoid suite intrusions (Smyk et al. 2002; Decharte et al. 2018).

The area covered by this article includes the granodioritic to monzodioritic Icarus pluton, which is a member of the sanukitoid suite (Stern, Hanson and Shirey 1989). Known mafic-ultramafic intrusions covered by this article intrude the quartz monzonitic to pyroxenitic

Jonsson, J.R.B. 2023. Nickel-copper-PGE potential in Archean intrusions of the Northern Light Lake area; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2022–2023, p.28-33.

Sleigh Lake pluton (Stern 1985) and an area of diorite-monzodiorite-syenite interpreted by Harris (1968) to be the fault-displaced northeastern margin of the Saganaga tonalite pluton. The Sleigh Lake pluton and the northeastern margin of the Saganaga pluton display some geochemical characteristics of the sanukitoid suite (LILE enrichment and syntectonic to posttectonic age), though neither has been definitively identified as being sanukitoid in composition (Stern, Hanson and Shirey 1989).

Detailed geological mapping has not been conducted in the area covered by this article, except for the westernmost extent, which was mapped by Harris (1968). Assessment reports on file with the Thunder Bay Resident Geologist's Office detail 2 significant historical claim groups in the area, both of which targeted Ni-Cu-PGE mineralization: 1) Robert De Carle staked several claims in the area and conducted prospecting programs in 1998 and 1999, identifying several mafic-ultramafic intrusions, 2 of which yielded anomalous assay results; and 2) HTX Minerals Ltd. staked a large claim block in 2008–2009, undertook a prospecting program in 2009, and optioned the property to Votorantim Metals Canada Inc. later that year (Mourre and Hrominchuk 2010). Votorantim conducted prospecting, soil sampling, a 2094 line-km versatile time-domain electromagnetic (VTEM) survey, and 3 diamond-drill holes in 2009. The reader is referred to the associated assessment files listed in the "References" section of this article (De Carle 1999; Mackie 2010) for detailed information on those programs.

Mafic-Ultramafic Intrusions

Prospective mafic-ultramafic intrusions in the area of Northern Light Lake (most of which are unnamed) are described below and outlined in Figures 1 and 2. These include the following areas:

1. Big Ghee Lake intrusion
2. northwest of Northern Light Lake
3. east of Weikwabinonaw River
4. east of Cannibal Lake

The Big Ghee Lake intrusion (Area 1; *see* Figures 1 and 2) is a 1750 by 2500 m, arcuate mafic-ultramafic complex described by De Carle (1999) as "composed of varitextured, medium-grained to pegmatitic gabbro to melagabbro, locally feldspathic hornblendite to clinopyroxene hornblendite, and hornblende clinopyroxenite". Prospecting by De Carle (1999) yielded anomalous assay values, in grab samples, of up to 1005 ppm Cu and up to 2620 ppm Ni, indicating base metal enrichment within the intrusive complex.

An approximately 300 m wide intrusion of varitextured, brecciated peridotite (Area 2; *see* Figures 1 and 2) located northwest of Northern Light Lake was identified and sampled by Mackie (2010). One grab sample returned >5000 ppm Zn, as well as 1616 ppm Cu and 60 ppb Au.

An approximately 700 by 300 m intrusion of "medium to very coarse-grained, locally feldspathic hornblende clinopyroxenite, clinopyroxene hornblendite, and moderately to strongly serpentinized to strongly talcose peridotite and dunite" (Area 3; *see* Figures 1 and 2) was located along an unnamed lake immediately east of the Weikwabinonaw River (De Carle 1999). Two sulphur-undersaturated grab samples from this intrusion yielded anomalous assay values. A strongly altered ultramafic dike crosscutting the intrusion returned 38 ppb Pd and 35 ppb Pt, and a sample of altered clinopyroxene hornblendite from the main intrusion returned 327 ppm Cu (De Carle 1999).

Harris (1968) briefly described an intrusion of diorite and/or gabbro (Area 4; *see* Figures 1 and 2) on the northeastern shore of Cannibal Lake, bound to the northwest by a kilometre-scale fault and containing up to 50% amphibole alongside rounded fine-grained phenocrysts of plagioclase. This intrusion was not covered by historical claims staked by De Carle or HTX/Votorantim.

Data published by Jackson (2001) delineates 2 north-trending lake sediment anomalies with high levels of Ni, Mg, Cr and titanium (Ti) directly north of Northern Light Lake. Some of the lakes sampled by Jackson in this area also contain anomalous levels of Pt, Pd, Cu and Au. Samples containing Ni and Pd values above the 80th percentile of the survey area are included in Figure 1. Further details on the nature and distribution of these anomalies can

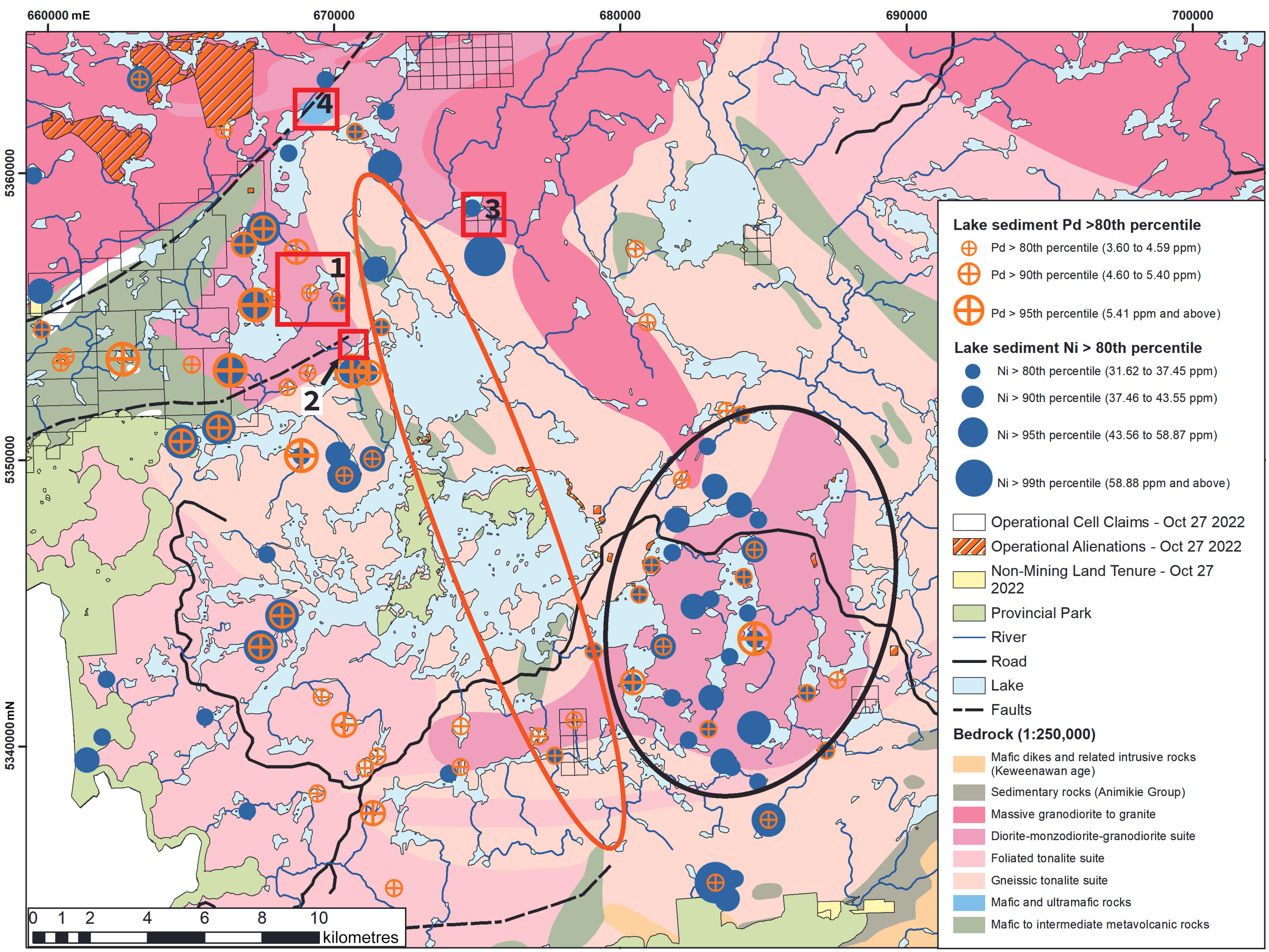

Figure 1. Location of target areas (in red boxes; *see* text for details), mining claims, and lake sediment nickel and palladium anomalies, overlain on bedrock geology. Regional north-northwest-trending magnetic expression indicated by orange oval. Icarus pluton indicated by black oval. Claim units current as of October 27, 2022. Geology *from* Ontario Geological Survey (2011); lake sediment data *from* Jackson (2001). Universal Transverse Mercator (UTM) co-ordinates in North American Datum 1983 (NAD83), Zone 15.

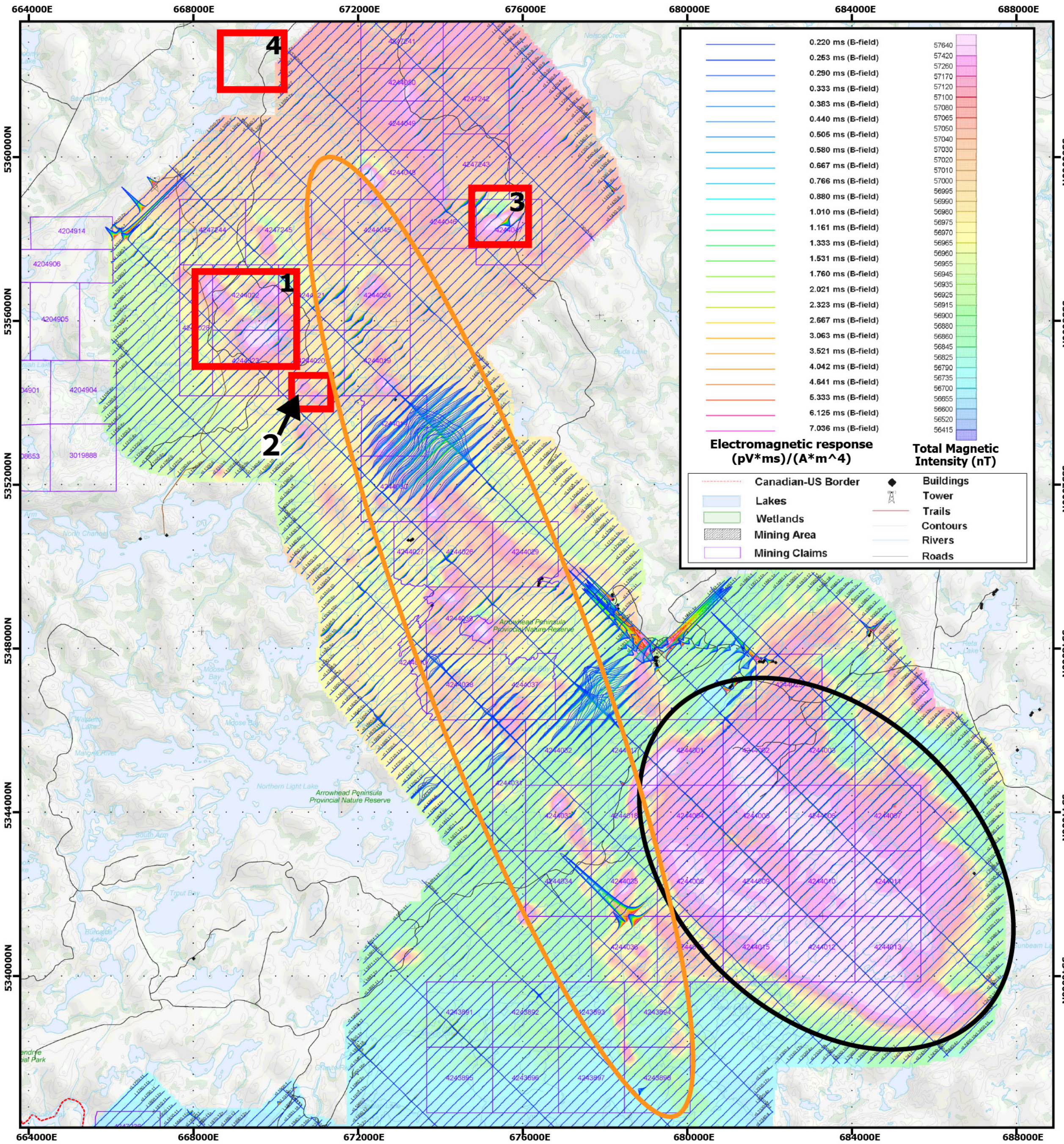

Figure 2. Location of target areas (in red boxes; *see* text for details) overlain on total magnetic intensity and versatile time-domain electromagnetic (VTEM) data (B-field Z component, time gates 0.220-0.7036 ms). Regional north-northwest-trending magnetic expression indicated by orange oval. Magnetic signature of Icarus pluton indicated by black oval. Claims units are historical. Geophysical data *from* HTX Minerals Corp. (2010). Universal Transverse Mercator (UTM) co-ordinates in North American Datum 1983 (NAD83), Zone 15.

be found in Jackson (2001). This area of lake sediment anomalies corresponds with the location of the mafic-ultramafic intrusions detailed above, extending south from some of the intrusions. The southward extent of these anomalies could potentially correspond with down-ice transport of sediment from the area of these intrusions, as Zoltai (1965) modeled a south to southwest direction of glacial ice movement in the area covered by this article, based on surficial features including striae, end moraines and eskers.

Icarus Pluton

The Icarus pluton is approximately 8 by 13 km in size, composed of a western aegirine-augite-bearing monozodioritic phase intruded by an eastern hornblende granodioritic phase (Goldich et al. 1972). The pluton is recognizable in regional geophysical surveys, showing a strong magnetic response and marginally elevated conductivity throughout its extent.

Regional sediment sampling programs conducted by the OGS have outlined anomalous metal content associated with the central, southern and western portions of the Icarus pluton (black oval on Figures 1 and 2). Lake sediment sampling data outlines a broad area of anomalous Cr, Cu and Ni overlying the pluton, as well as single samples of anomalous Pt, Pd and Au (Jackson 2001). The area of these anomalies is coincident with an area of anomalous chrome diopside, Cr, Cu, Ni and silver (Ag) delineated within glacial till between Icarus Lake and Sunbow Lake (Marich 2015). In addition to the OGS sampling programs, a stream sediment sample taken by De Carle (1999) between Icarus Lake and Sunbow Lake yielded a result of 73 ppb Au.

Discussion and Recommendations

The presence of anomalous metal grades in mafic-ultramafic intrusive rocks alongside magnetic, conductivity and surface sediment anomalies, warrants further investigation for Ni-Cu-PGE mineralization. Although conductivity anomalies associated with some of these intrusions are relatively weak, this can potentially be indicative of "Type II" Ni-Cu-PGE mineralization (Lesher and Keays 2002), in which sulphide mineralization occurs as stratabound disseminated to net-textured horizons. When enriched in PGEs, this style of deposit can be economically significant despite low (<5%) quantities of sulphide minerals. Samples from both the Big Ghee Lake intrusion and the intrusion east of Weikwabinonaw River contain anomalous PGE content within sulphur-undersaturated rocks (<0.01% sulphur) (De Carle 1999). This is an indication that sulphur saturation did not occur prior to emplacement in the magma chamber and that a PGE-rich sulphide zone may exist within the intrusion (Hamlyn and Keays 1986). Detailed mapping and sampling of these compositionally heterogeneous intrusions is recommended to improve understanding of their crystallization history.

No mafic-ultramafic intrusive rocks associated with the Icarus pluton have been discovered to date, aside from an area of gneissic mafic intrusive rocks on the northwest edge of the pluton described by Mackie (2010). Because of the strong positive magnetic response of the pluton (*see* Figure 2), it is difficult to easily identify the presence of mafic-ultramafic rock types in district-scale geophysical surveys. Detailed ground-based prospecting and small-scale magnetic and/or electromagnetic surveying are recommended for this area.

The known mafic-ultramafic intrusions in the area covered by this article are believed to be of Archean age because of the degree of alteration of mafic minerals and the fact that they are commonly crosscut by felsic to intermediate dikes (Mackie 2010). Although this article focuses on interpreted Archean rock types, this area may also be prospective for Proterozoic Ni-Cu-PGE-mineralized intrusions related to the Midcontinent Rift (MCR). Both historical claim blocks discussed in this article were staked to primarily explore for MCR-related mineralization. A past OGS Recommendation for Exploration (Puumala and Campbell 2016) recommended a larger area that includes the area covered by this article as being prospective for MCR-related mineralization. Notably, a sinuous north-northwest-trending expression of discrete magnetic anomalies is present through the centre of the area surveyed by Votorantim (*see* Figure 2). The southern extent of this trend is located approximately 10 km north of the northern boundary of the MCR-associated Duluth complex, and it has been speculated that this trend could potentially represent a magma conduit (Mackie 2010). The majority of this trend has not been systematically explored and most of the anomalous areas remain unexplained (Mackie 2010; Mourre and Hrominchuk 2010).

References

De Carle, R.J. 1999. Assessment report: A Cu-Ni-PGE-Au project, Big Ghee Lake property; unpublished report, Thunder Bay Resident Geologist's Office, assessment file 52B07SE2001, AFRO# 2.19919, 115p.

Decharte, D., Hofton, T., Marrs, G., Olson, S., Peck, D., Perusse, C., Roney, C., Taylor, S., Thibodeau, D. and Young, B. 2018. Feasibility study for Lac des Ile Mine incorporating underground mining of the Roby Zone; NI 43-101-compliant Technical Report prepared for North American Palladium Ltd., filed with Sedar®, *see* SEDAR Home Page, 297p.

Goldich, S.S., Hanson, G.N., Hallford, C.R. and Mudrey, M.G., Jr. 1972. Early Precambrian rocks in the Saganaga Lake–Northern Light Lake area, Minnesota–Ontario: Part I. Petrology and structure; *in* Studies in Mineralogy and Precambrian Geology, Geological Society of America, Memoir 135, p.151-177.

Hamlyn, P.R. and Keays, R.R. 1986. Sulfur saturation and second-stage melts; application to the Bushveld platinum metal deposits; Economic Geology, v.81, p.1431-1445.

Harris, F.R. 1968. Geology of the Saganagons Lake area; District of Thunder Bay, Ontario Department of Mines, Geological Report 66, 30p.

HTX Minerals Corp. 2010. Maps, drill plans, and drill sections for the diamond drill program, Icarus claim group; Thunder Bay Resident Geologist's Office, assessment file 20000005805, AFRO# 2.47044, 11p.

Jackson, J.E. 2001. Shebandowan area high-density regional lake sediment and water geochemical survey, northwestern Ontario; Ontario Geological Survey, Open File Report 6057, 83p.

Lesher, C.M. and Keays, R.R. 2002. Komatiite-associated Ni-Cu-(PGE) deposits: Mineralogy, geochemistry, and genesis; *in* The Geology, Geochemistry, Mineralogy, and Mineral Beneficiation of the Platinum-Group Elements; Canadian Institute of Mining, Metallurgy, and Petroleum, Special Volume 54, p.579-617.

Mackie, B.W. 2010. Report on the Icarus claim group; unpublished report for Votorantim Metals Canada Inc., Thunder Bay Resident Geologist's Office, assessment file 20000005805, AFRO# 2.47044, 114p.

Marich, A.S. 2015. Results of regional till sampling in the Mowe Lake area, northwestern Ontario; Ontario Geological Survey, Open File Report 6308, 66p.

Mourre, G. and Hrominchuk, J. 2010. Report on the 2008–2010 Icarus property exploration programs; unpublished report for Votorantim Metals Canada Inc., Thunder Bay Resident Geologist's Office, assessment file 20000005805, AFRO# 2.47044, 84p.

Ontario Geological Survey 2011. 1:250 000 scale bedrock geology of Ontario: Ontario Geological Survey, Miscellaneous Release—Data 126–Revision 1.

Puumala, M.A. and Campbell, D.A. 2016. Copper-nickel-platinum group element potential in the area between Northern Light Lake and Batwing Lake; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2015–2016, p.15-17.

Smyk, M.C., Mason, J.K., Schnieders, B.R. and Stott, G.M. 2002. A synopsis of Archean and Proterozoic platinum group element mineralization in the Thunder Bay District, Ontario; extended abstract *in* 9th International Platinum Symposium, Billings, Montana, July 25, 2002, p.433-434.

Stern, R.A. 1985. Field setting of crescentic intermediate plutons; *in* Regional Geological Synthesis of Western Superior Province, Ontario, Current Research, Geological Survey of Canada, Paper 85-1A, Part A, p.389-392.

Stern, R.A., Hanson, G.N. and Shirey, S.B. 1989. Petrogenesis of mantle-derived, LILE-enriched Archean monzodiorites and trachyandesites (sanukitoids) in southwestern Superior Province; Canadian Journal of Earth Sciences, v.26, p.1688-1712.

Williams, H.R., Stott, G.M., Heather, K.B., Muir, T.L. and Sage, R.P. 1991. Wawa Subprovince; *in* Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part 1, p.485-541.

Zoltai, S.C. 1965. Glacial features of the Quetico–Nipigon area, Ontario; Canadian Journal of Earth Sciences, v.2, p.247-269.

7

HIGHLIGHTS

- **Mafic to ultramafic rocks located southwest and west of past-producing Ni-Cu-Co-PGE Shebandowan Mine has seen limited exploration over the past 60 years**
- **OGS till sampling program (2000) covering the western part of the Shebandowan greenstone belt indicates base metal exploration targets**
- **Patterns depicted by anomalous Ni-Cr-Co-Cu-PGE till results are similar in many respects and closely tied to the distribution of Archean mafic and ultramafic rocks**

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Nickel-Copper-Cobalt-PGE Potential in the Shebandowan–Greenwater Lakes Area

Limited exploration has been undertaken in Archean mafic to ultramafic rocks in the Greenwater Lake area, southwest and west of the past-producing nickel-copper-cobalt-platinum group element (Ni-Cu-Co-PGE) Shebandowan Mine (Figures 1 to 6). The northeast-trending mafic to ultramafic rocks are generally sill-like bodies, conformable to the local stratigraphy within an assemblage of metavolcanic rocks of the Shebandowan greenstone belt in the Wawa Subprovince (Osmani 1997).

Nickel-copper ore was discovered on the shoreline of Lower Shebandowan Lake, at Discovery Point by prospector Julian Cross in 1913. Little to no exploration was carried out until 1936. Subsequently, it was another 30 years before the Shebandowan Mine was developed, as most of the deposit was located under the lake. The average width of the ore body was approximately 7.5 m and was mined over a strike length of 3.5 km to a maximum depth of 1000 m (Inco 2001). The Shebandowan Mine produced 9.29 million tonnes of ore at 1.75% Ni, 0.88% Cu, 0.063% Co, 0.0533 oz/ton PGEs and 0.0575 oz/ton Ag (Inco 2001). The Shebandowan deposit has been traditionally considered to be hosted by a serpentinized peridotite sill that forms part of a mafic metavolcanic rock-dominated sequence (Osmani 1997). New evidence suggests, however, that these host rocks may in fact be komatiitic flows (Aubut and Campbell 2012), which has implications for the possible localization of magmatic sulphide Ni-Cu-Co-PGE mineralization at the basal contacts.

The Ontario Geological Survey (OGS) completed a till sampling program covering the western part of the Shebandowan greenstone belt, clearly identifying several precious and base metal exploration targets (Bajc 2000). This article will highlight 2 areas with clusters of Ni-Cu-Co-Cr-Pt-Pd till anomalies located east and west of Greenwater Lake, as shown by red ovals in Figures 1 to 6. Bajc (2000) reports the patterns depicted by the Ni-Cr-Co results are similar, in many respects, and closely tied, to the distribution of mafic and ultramafic rocks. The highlighted areas have had limited exploration for Ni-Cu-Co-PGE and follow-up programs were recommended by Bajc (2000) to determine the significance of the anomalies and more precisely define potential source rocks. Previous work in these highlighted areas focused mostly on exploration for gold; however, exploration for base metals should not be overlooked. In the Shebandowan area, Osmani (1997) suggests gold may have been introduced during the D2 event superimposed on the existing pre-D2 volcanogenic and magmatic base metal deposits (copper, nickel, zinc, etc.).

Campbell, D.A. 2023. Nickel-copper-cobalt-PGE potential in the Shebandowan–Greenwater Lakes area; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2022–2023, p.34-40.

East Greenwater Lake Area

The highest Ni-Co-Cr anomalies reported in the till survey (Bajc 2000) occur within Begin Township, east of Greenwater Lake, and are situated on the north side of Pinecone Lake, returning 345 ppm Ni, 44 ppm Co and 398 ppm Cr (Figures 1 to 3). At this location, Cu and Pt values are considered anomalous as they fall into the "greater than 95th percentile" and Pd is slightly elevated (Figures 4 to 6). An electromagnetic (EM) anomaly correlates with this location and several more EM anomalies occur along the stratigraphic trend to the southwest of Pinecone Lake. The reader is referred to OGS (1991) airborne electromagnetic survey, Map 81 575. Osmani (1997) mapped mafic to ultramafic rocks in this area and reported an outcrop of polysutured ultramafic metavolcanic flows approximately 460 m west of Pinecone Lake. The ultramafic flows are generally massive, rarely polysutured and lack diagnostic primary features such as spinifex texture or pillows. Some ultramafic rocks, especially the polysutured variety mapped as sills, may be flows. The contact relationship between mafic metavolcanic and ultramafic rocks is rarely observed and is generally obscured by shearing and/or by intense alteration (e.g., iron-carbonatization and serpentinization). South of Pinecone Lake, Osmani (1997) reported gabbro and amphibolite with associated pyrite and chalcopyrite mineralization within subsidiary faults associated with the Tinto Lake fault zone. It should be noted that prior to the release of the OGS till survey, Osmani (1997) recommended these mafic to ultramafic rocks be investigated for base and precious metal mineralization.

In the Star Lake area, several Ni-Cu-Co-Cr-Pt till anomalies (Figures 1 to 5) occur within the Star Lake mafic to ultramafic sill-complex (SMUC), just east of Greenwater Lake. The Star Lake area till anomalies returned values of up to 191 ppm Ni, 42 ppm Co, 239 ppm Cr and 3.6 ppb Pt (Bajc 2000). The SMUC is approximately 900 m by 6.5 km in extent and is situated north of Star Lake. The north and south margins of the SMUC consists of peridotite to pyroxenite while the core of the SMUC mainly consists of gabbro to anorthositic gabbro showing magmatic layering (Osmani 1997). In 1990, Mingold Resources Inc. carried out a till sampling program in the Star Lake area, focusing mostly on gold exploration (Bidwell 1990). The Mingold till survey identified several gold anomalies; however, follow-up work was minimal. In 1994–95, B. Kowalski carried out exploration programs in the Star Lake area consisting of prospecting, geological mapping, sampling and ground geophysics. Kowalski (1995, 1996) reported grab samples collected in an area northwest of Star Lake, from peridotite and gabbro with associated pyrite and pyrrhotite mineralization, returned anomalous values of Ni (521, 602, 656, 740, 792, 796 ppm) and Cr (1192, 1694, 1810 ppm). A grab sample from a float returned 1533 ppb Au and a duplicate assay of 1135 ppb Au (Kowalski 1996).

Follow-up exploration is also recommended north of the SMUC, where several other mafic to ultramafic rocks with correlating Ni-Co-Cr ±Cu ±Pt ±Pd till anomalies are situated (Figures 1 to 6). At the time of writing this article, an area open for acquisition (approximately 16 to 20 cells) with 2 anomalous Ni-Co-Cr till sites (correlating mafic to ultramafic bodies) situated 1.5 to 2 km north of Star Lake, returned the following results: 103 ppm Ni, 25 ppm Co, 168 ppm Cr, 78 ppm Ni, 22 ppm Co, 88 ppm Cr, and 68 ppm Ni, 28 ppm Co, 99 ppm Cr (Bajc 2000). In 1967, Falconbridge completed drilling just south of the 2 anomalous Ni-Co-Cr till sites; however, no assays were provided. The drill logs indicate zones of peridotite and gabbro rocks with some altered sections (serpentinized, talc schists), faults, shear zones, breccias and chlorite-fuchsite schists with sections containing 5 to 40% pyrite and 2 to 3% pyrrhotite (Harrison and Trusler 1968; Harrison 1968).

With the glacial ice direction to the southwest, it's fair to question whether the till anomalies are sourced from the Shebandowan Mine area. Bajc (2000) explains

> There is very little, if any, geochemical evidence of the Shebandowan Ni-Cu-PGE deposit. This is most likely a result of the extremely narrow nature of the peridotite body (less than a few hundred metres) that hosts Ni-Cu mineralization at the mine site, the recessive nature of the orebody (i.e. it lies mostly beneath the lake) and the lack of samples in the immediate down-ice direction from the ore body. Glaciofluvial and glaciolacustrine deposits are abundant proximal to the mine site.

Bajc (2000) summarizes

> The large area of elevated to anomalous Ni-Cr-Co within Begin Township defines an area within which favourable source rocks occur. Elevated to anomalous Pt and Pd values from the southern edge of this anomaly are spatially associated with mafic and ultramafic intrusive rocks including gabbros, peridotites and anorthositic gabbros. Additional till sampling and prospecting should be undertaken within this area to more fully investigate the anomaly.

With the volume of mafic to ultramafic rocks situated in the area southwest of the Shebandowan Mine, the potential for additional Ni-Cu deposits, as seen in the Mt. Keith–Kambalda region (Western Australia), should not be overlooked.

West Greenwater Lake Area

A cluster of Ni-Cu-Co-Cr-Pd till anomalies (Bajc 2000) occur at the south end of Upper Shebandowan Lake (Figures 1 to 4, 6). In this area, Osmani (1997) mapped predominately mafic intrusive rocks (gabbro-anorthosite bodies and/or sills) within an assemblage of mostly intermediate to mafic metavolcanic rocks. The till anomalies are proximal to the Upper Shebandowan Lake Shear Zone System (South Branch), where gabbroic rocks are sheared and altered to chlorite-epidote-actinolite-hornblende schists. Minor ultramafic rocks (peridotites) are conformable to the local stratigraphy.

Nickel-copper-cobalt-PGE deposits are generally too small to be readily identified in regional-scale geophysical programs; however, regional surveys are an effective tool for reconnaissance-scale exploration. Areas that were previously explored for base metals west and southwest of the Shebandowan Mine warrant (re-)investigation, especially considering new advances in geophysics, geological concepts, geochemical analysis and lower detection limits, as well as the increased demand for Ni, Cu and PGEs, increased commodity prices and increased metal recovery methods. The areas recommended in this article are acquired at the time of publication; however, these areas are available for option from local geologists and prospectors: D. Parker, D. Hoy, J. Hackl, E. Holbik, J. Kulp, R. Angove and J. Ternowesky.

Figures 1 to 6, below. Regional geological maps (geology *from* Ontario Geological Survey 2011) superimposed on the total magnetic shadow field (*from* Ontario Geological Survey 2003), highlighting 2 areas (red ovals) with clusters of OGS till anomalies (black dots) west of the Ni-Cu-Co-PGE Shebandowan Mine site (black triangles). Magnetic anomalies (high magnetic relief), mafic to ultramafic rocks shown in blue; granitoid rocks, in various shades of pink; metavolcanic rocks, in various shades of green; metasedimentary rocks, in grey; faults, as black dashed lines.

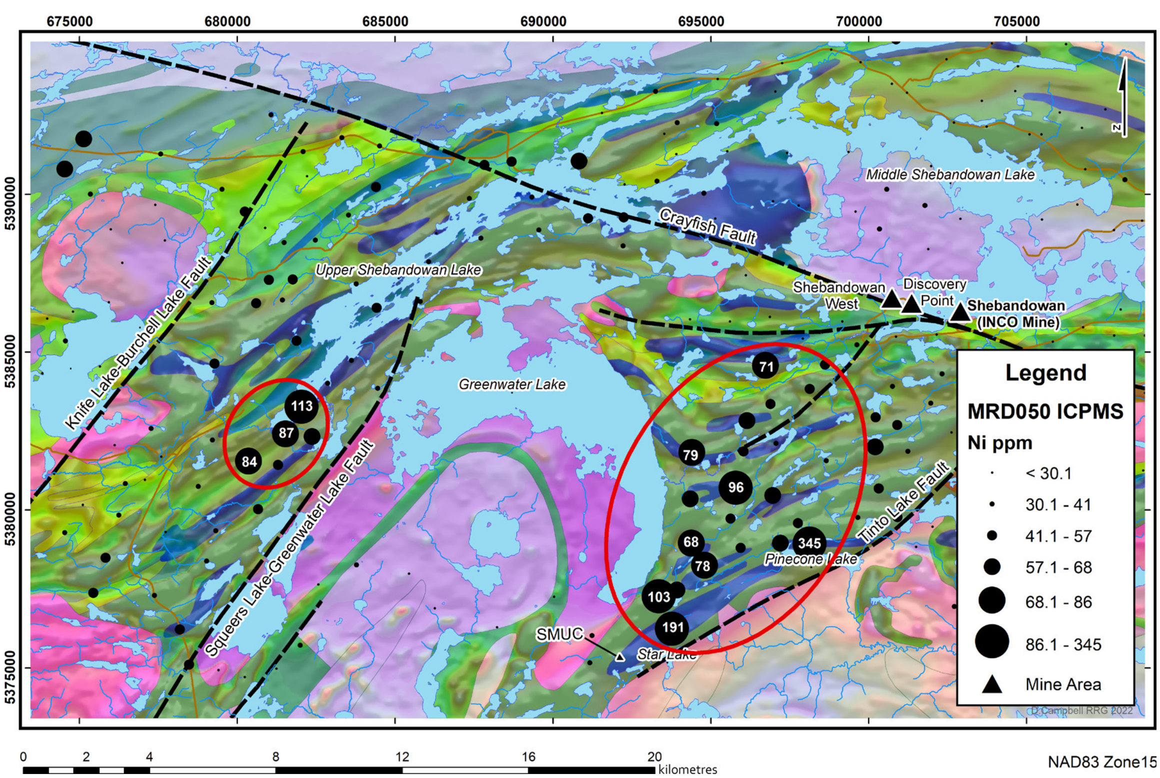

Figure 1. Nickel (Ni) till anomalies (black dots, with ppm values indicated in white font), *modified from* Bajc (2000).

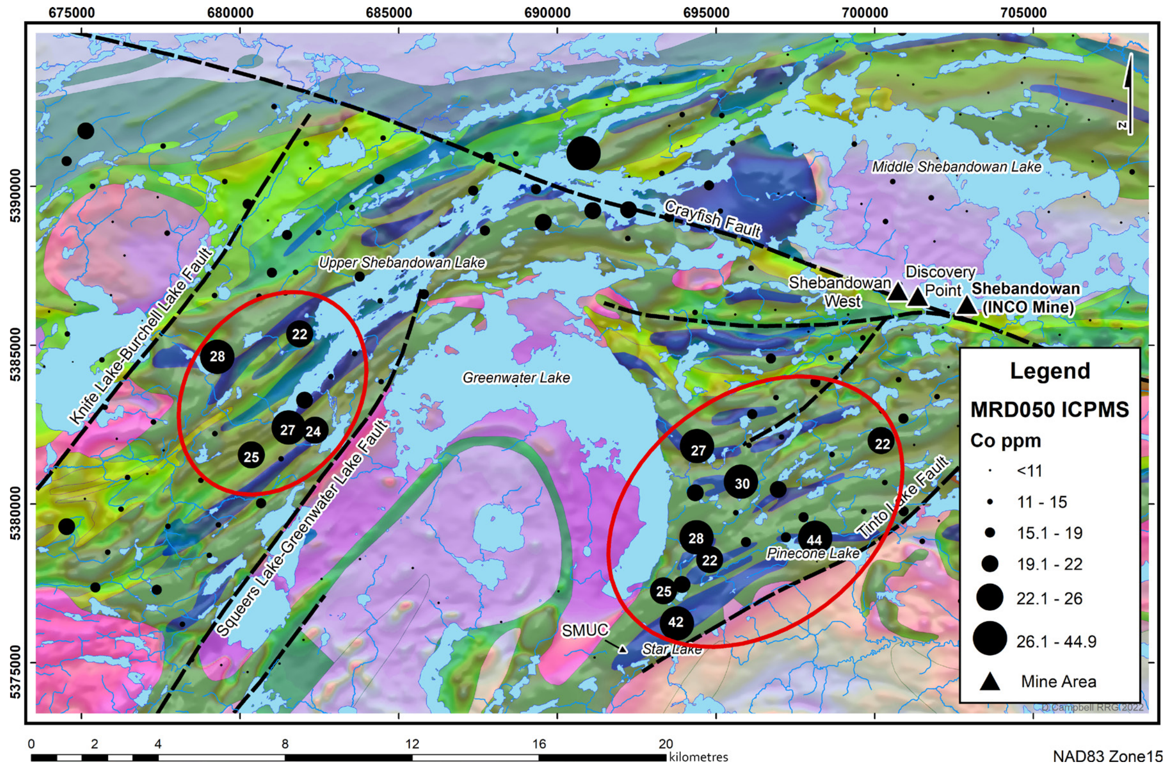

Figure 2. Cobalt (Co) till anomalies (black dots, with ppm values indicated in white font), *modified from* Bajc (2000).

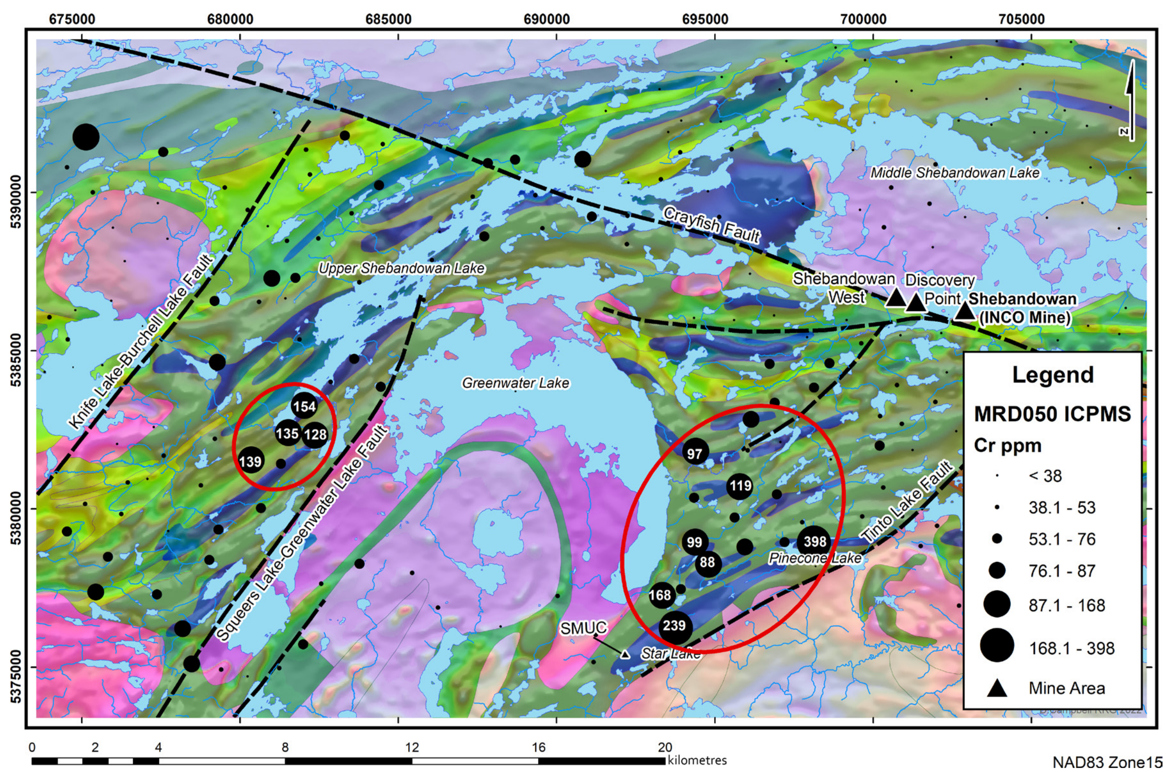

Figure 3. Chromium (Cr) till anomalies (black dots, with ppm values indicated in white font), *modified from* Bajc (2000).

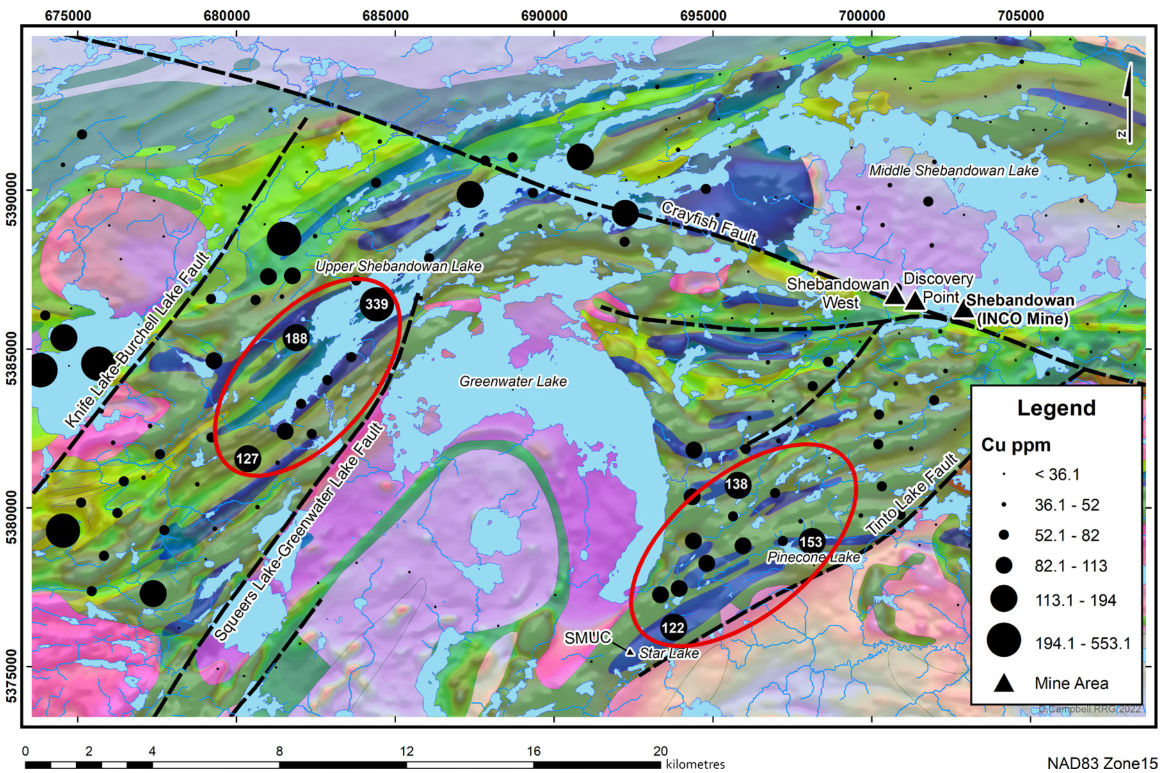

Figure 4. Copper (Cu) till anomalies (black dots, with ppm values indicated in white font), *modified from* Bajc (2000).

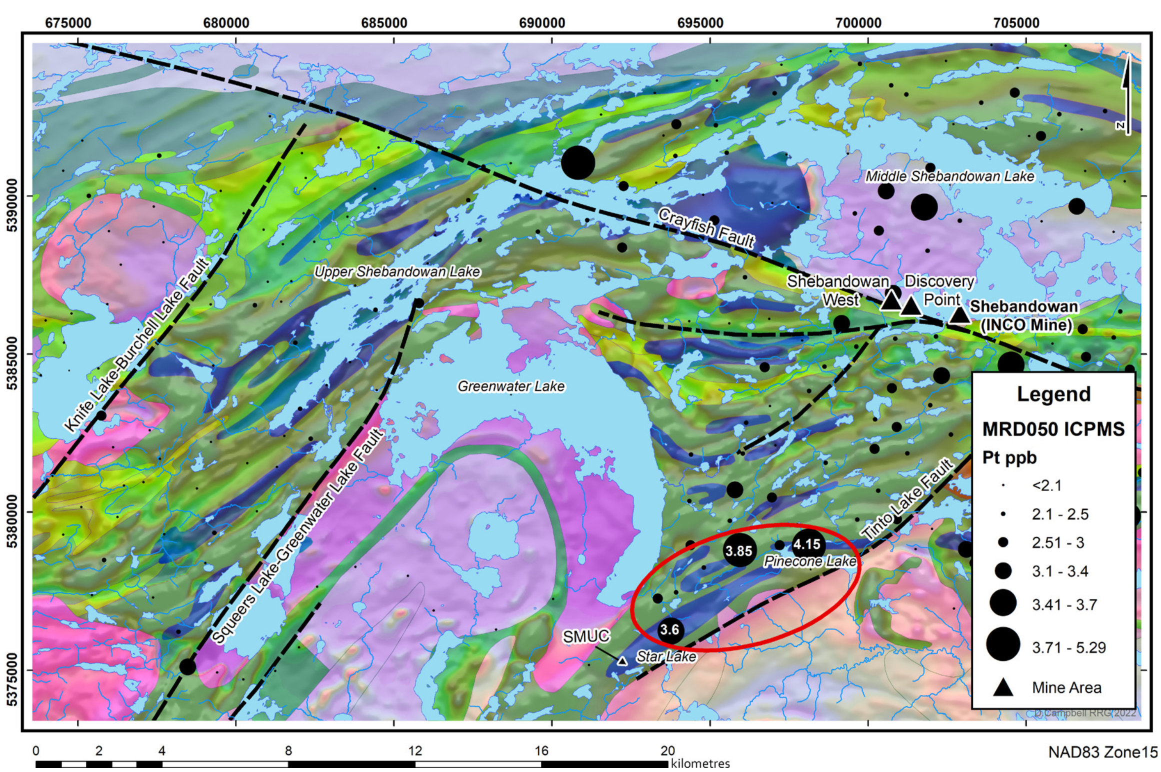

Figure 5. Platinum (Pt) till anomalies (black dots, with ppb values indicated in white font), *modified from* Bajc (2000).

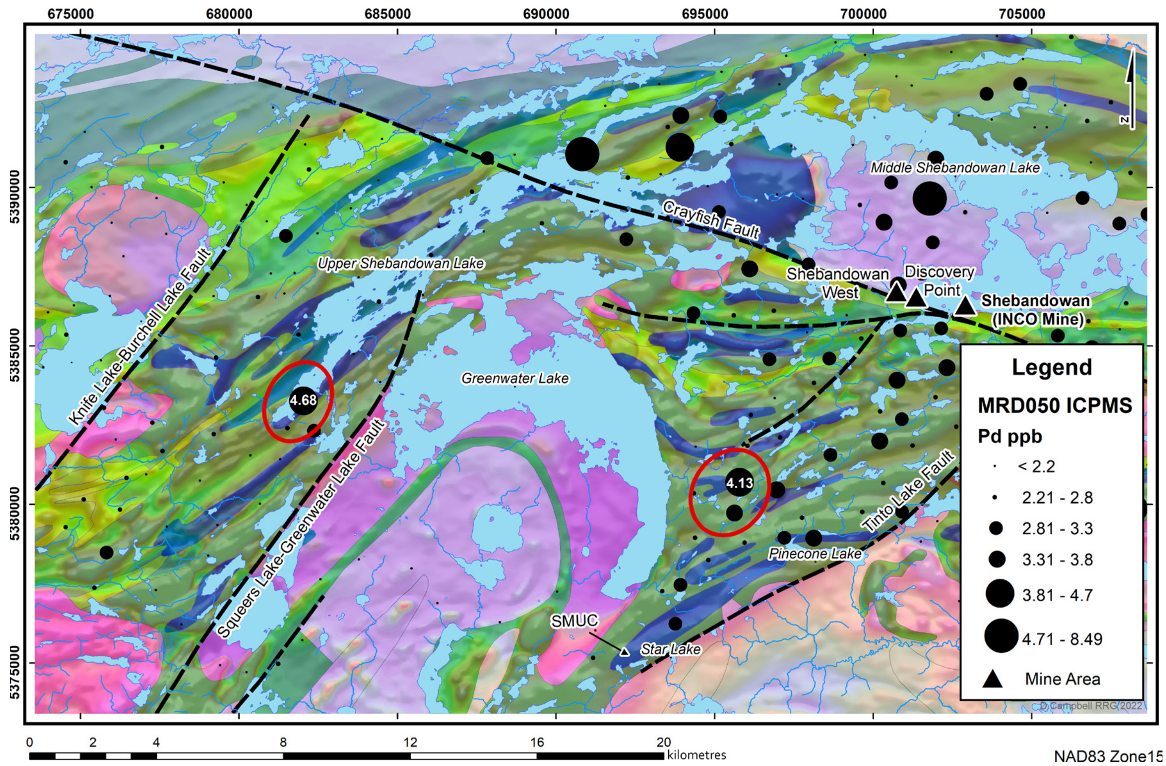

Figure 6. Palladium (Pd) till anomalies (black dots, ppb values indicated in white font), *modified from* Bajc (2000).

References

Aubut, A. and Campbell, D. 2012. Shebandowan Mine area; in Institute on Lake Superior Geology Proceedings, 58th Annual Meeting, Thunder Bay, Ontario, Part 2 – Field Trip Guidebook, v.58, pt.2, p.67-73.

Bajc, A.F. 2000. Results of regional till sampling in the western part of the Shebandowan greenstone belt, northwestern Ontario; Ontario Geological Survey, Open File Report 6012, 74p. Associated data set: Miscellaneous Release—Data 50 http://www.geologyontario.mndm.gov.on.ca/mndmaccess/mndm_dir.asp?type=pub&id=MRD050

Bidwell, G.E. 1990. Mingold Resources Inc., Quetico (Reconnaissance) project, OMIP Program No. OM90-094 bulk till sampling program, May–November 1990, Thunder Bay and Kenora Mining Divisions, Thunder Bay South Resident Geologist's Office, assessment file 52F04NE9650, AFRO# 63.6161, 71p.

Harrison, W.D. 1968. Diamond drilling by Falconbridge Nickel Mines, Begin Township, Thunder Bay South Resident Geologist's Office, assessment file 52B09SW8280, 21p.

Harrison, W.D. and Trusler, J. 1968. Diamond drilling by Falconbridge Nickel Mines, Begin Township, Thunder Bay South Resident Geologist's Office, assessment file 52B09SW0055, 31p.

Inco Limited Ontario Division 2001. Shebandowan Mine closure plan Part I of II; unpublished report, Ministry of Northern Development and Mines, Thunder Bay, Mines and Minerals Division office, 84p.

Kowalski, B. 1995. OPAP 1994 final submission on the Star Lake property (Greenwater Lake area), Begin Township, Thunder Bay South Resident Geologist's Office, assessment file 52B09SW0004, AFRO# 2.15870, 28p.

——— 1996. OPAP 1995 final submission on the Star Lake property (Greenwater Lake area), Begin Township, Thunder Bay South Resident Geologist's Office, assessment file 52B09SW0028, AFRO# 2.16489, 36p.

Ontario Geological Survey 1991. Airborne electromagnetic and total intensity magnetic survey, Shebandowan area; Ontario Geological Survey, Map 81 575, scale 1:20 000.

——— 2003. Airborne geophysical surveys, magnetic and electromagnetic data (ASCII and Geosoft® formats) Shebandowan area; Ontario Geological Survey, Geophysical Data Set 1021.

——— 2011. 1:250 000 scale bedrock geology of Ontario; Ontario Geological Survey, Miscellaneous Release—Data 126–Revision 1.

Osmani, I.A. 1997. Geology and mineral potential: Greenwater Lake area, west-central Shebandowan greenstone belt; Ontario Geological Survey, Report 296, 135p.

HIGHLIGHTS

- **Increasing demand for microdiamonds in industrial applications**
- **Large portion of land towards the east of the Wawa region remain relatively under explored**

The Hunt for Diamonds and Microdiamonds East of Wawa

Diamonds are the hardest known substance composed of a single element – carbon. Apart from their beauty, diamonds are known for their unique chemical and physical properties and have thus been a valuable commodity for industrial applications. Diamonds have been used as an abrasive in cutting, drilling, grinding and polishing for centuries. Other applications include its use for heat sinks in electronic components, windows, manufacturing of tungsten wires, smartphone screens, surgical tools, optical components, audio equipment and in beauty products. In the last 25 years the search for microdiamonds has gained importance. Microdiamonds were previously ignored because of their poor size and difficulty in extraction. As techniques for extraction have improved, the industrial demand and application of microdiamonds has also increased (Trautman, Griffin and Scharf 1998). In exploration, microdiamond analysis has been used to confirm their presence and to estimate the microdiamond potential in a kimberlite pipe. A new imaging technique that utilizes microdiamonds as biological tracers shows promise for enhanced optical imaging (www.laserfocusworld.com/detectors-imaging/article/14203574/microdiamonds-boost-both-optical-imaging-mri [accessed October 16, 2022]).

In 2021, the global market for diamonds was valued at US$94.96 billion. It is expected to grow at a compound annual growth rate of 4.4% from 2022–2030, with the market expected to reach US$139.91 billion by 2030 (https://straitsresearch.com/report/diamond-market [accessed November 10, 2022]).

Geology and Past Exploration

Wawa and the surrounding areas have witnessed significant diamond exploration in the past. The focus of this recommendation is on the areas around Kinniwabi Lake and the Kap-South Project. The Kinniwabi Lake area is located to the east of Wawa, south of the Great Lakes–Hudson Bay regional drainage divide. Canabrava Diamond Corporation's former Kap-South Project encompasses areas around Bolkow Lake in the townships of Bader, Lang, Collishaw and Marsh. The areas recommended for exploration (Figure 1) lie within the Wawa assemblage of the Michipicoten greenstone belt, the largest belt within the Wawa Subprovince (Sage 1994). The Kapuskasing Structural Zone (KSZ) is significant because it consists of fractured crustal material that may host kimberlite (Boland and Ellis 1989). The KSZ extends from the east shore of Lake Superior to the northeast, through the town of Kapuskasing and into the Hudson Bay Lowland. The Quaternary deposits in the area are thought to be of Late Wisconsinan age or younger (Morris 1992).

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Adrianwalla, C.J. 2023. The hunt for diamonds and microdiamonds east of Wawa; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2022–2023, p.41-44.

In the summer of 1991, 2 diamonds of industrial quality were found in the Michipicoten River, in the Wawa area, by a local prospector. To establish authenticity of these discoveries, the Ontario Geological Survey (OGS) initiated a sampling program. From the reported discovery sites, ten 25 kg samples were collected. Sampling yielded kimberlite indicator minerals (KIMs), a G-10 garnet grain and 9 chrome diopside grains (Morris, Murray and Crabtree 1994). Following these results, the OGS conducted a modern alluvium sampling program in 1994. A total of 250, 10 kg samples were taken from Quaternary deposits. Sampling identified 41 chrome pyrope garnet grains (4 G10 grains), 108 chromite grains (5 of diamond association), 121 Mg-ilmenite grains and 39 chrome diopside grains (Morris, Murray and Crabtree 1994).

In 1996, the OGS initiated a second modern alluvium- and till-sampling program in the Kinniwabi Lake area. Most kimberlite indicator minerals recovered during this sampling program were from streams associated with major faults.

From the sampling program 157 samples were collected. Sampling identified 26 chrome pyrope grains (3 G10 grains), 110 chromite grains (1 high-chrome chromite), 171 Mg-Ilmenite grains and 279 chrome diopside grains. The sampling around the Kinniwabi Lake area outlined 4 areas with significant concentrations of KIMs (*see* Figure 2). Outside of those areas, near Lake Kinniwabi, a significant number of KIMs were recovered as well. The study also suggests that the KIMs were close to the source because of the presence of olivine, perovskite rinds, resorbed surfaces and oxidized rinds on Mg-ilmenite grains (Morris, Crabtree and Pianosi 1997).

KM Diamond Exploration Ltd., per an agreement with Canabrava Diamond Corp., conducted significant exploration in the Whitefish Lake and Kapuskasing areas in the late 1990s. Prospecting for kimberlite, sampling for KIMs, geochemical analysis, along with geophysical activities, were conducted on the property located in the townships of Debassige, Bader, Cowie, Debassige, Echum, Esquega, Fiddler, Isaac, Keesickquayash, Laforme, Lastheels, Maness, Michano, Miskokomon, Nadjiwon, Pawis, Quill and Recollet. The company identified several promising areas for kimberlite exploration.

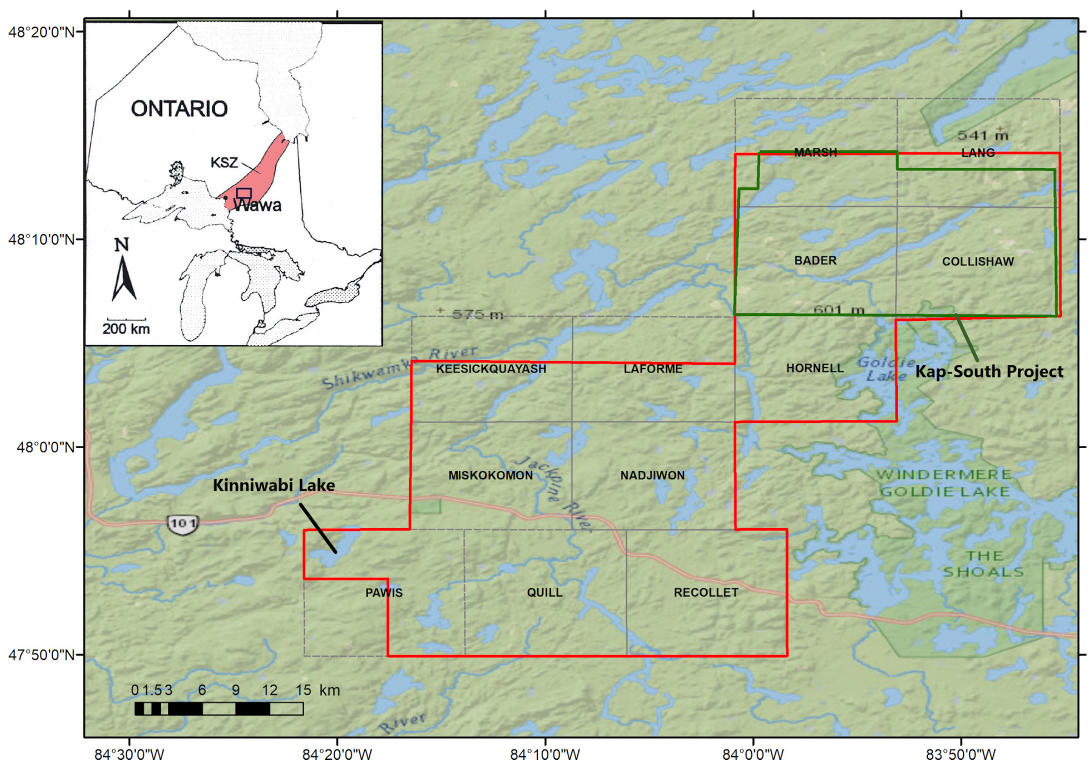

Figure 1. Map showing the areas recommended for exploration within the highlighted (outlined in red) townships. The inset map shows location of the Kapuskasing Structural Zone (KSZ) (*from* Sage 1992).

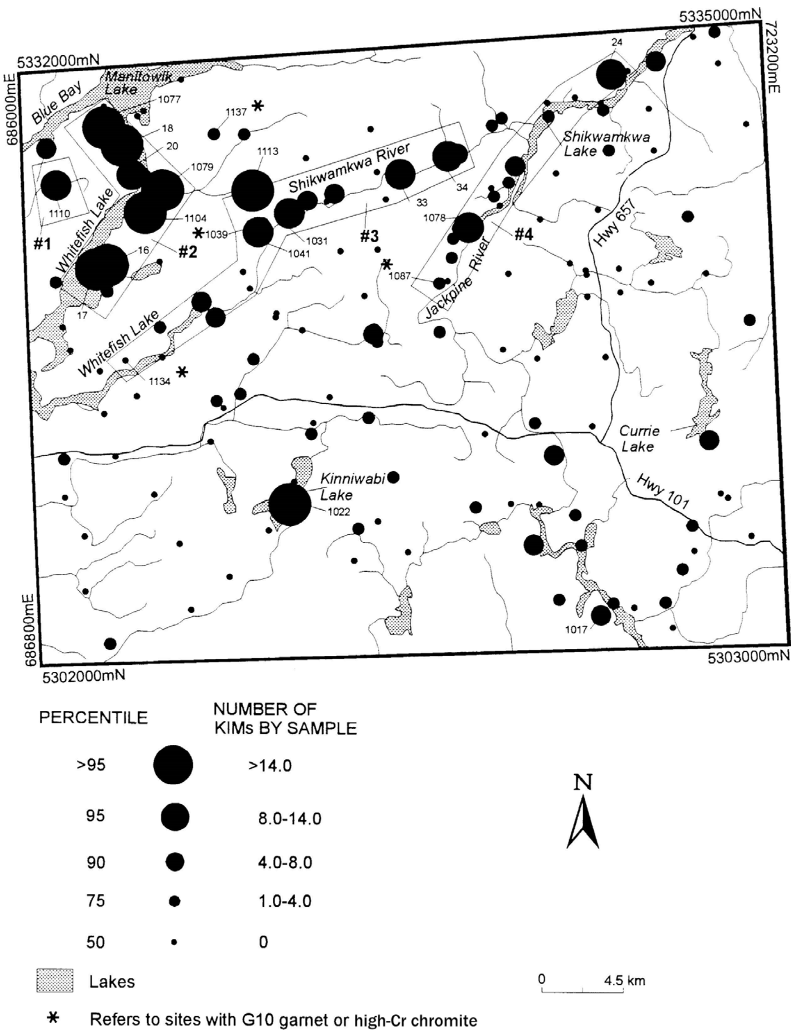

Figure 2. Distribution of kimberlite indicator minerals for the Kinniwabi Lake area. Numbered boxes refer to sample site locations with significant concentrations of kimberlite indicator minerals (*from* Morris, Crabtree and Pianosi 1997).

In 1997 KM Diamond Exploration Ltd. identified 2 kimberlite intrusions, #115 and #121. These intrusions are similar to Group-1 kimberlites. These kimberlites were dated at 1097±7 Ma. The northwest portion of the Whitefish Lake area was the most prospective for kimberlite (Kaminsky, Shchukin and Istomine 1997; Kaminsky et al. 1999a, 1999b). Mineralogical examinations of panned samples identified a large quantity of KIM grains in the Kap-South Project area located in the townships of Marsh, Bader, Lang and Collishaw. The area was identified as most promising for kimberlite and diamonds. Picroilmenite was the most abundant KIM in the area (Kaminsky, Shchukin and Istomine 1997; Kaminsky et al. 1999a, 1999b).

Recommendations for Exploration

A considerable amount of exploration work has been conducted within the Wawa region. At the time of writing this report, there is significant land open for registration in areas proximal to mineral occurrences identified in the region. Compilation of the distribution of KIMs from both the 1994 and 1996 OGS surveys indicates that the most promising kimberlite target areas in the Wawa region occur in fault-controlled valleys. Subparallel or orthogonal faults within the KSZ may also represent good targets for kimberlite exploration (Morris, Crabtree and Pianosi 1997). The townships of Quill, Recollet, Miskokomon, Keesickquaysh, Nadjiwon, Laforme, Hornell, Bader, Marsh, Collishaw and Lang fall within the KSZ and have significant land to register claims at the time of writing.

Prospecting in these areas for kimberlites and diamonds should be considered because exploration techniques have significantly improved. Additionally, the data available from past exploration, assessment files, drill-hole information, mineral occurrences and other OGS data sets provide a wealth of information to help model and target kimberlites and diamonds.

Recommendations for exploring kimberlites and diamonds within these areas, including advice from sources such as Morris, Crabtree and Pianosi (1997), Stephenson, Morris and Crabtree (1999) and Kaminsky et al. (1999a, 1999b), are listed below.

- Panning should be used in direct search for kimberlites.
- The study of KIM grain surfaces is informative and useful for prospecting.
- A sample site with a predominant local mix of pebbles may suggest proximity to the source.
- Ground magnetic surveys should be organized in areas where kimberlites have been discovered to establish kimberlite configuration and size.
- Aeromagnetic data is useful in estimating the proximity of KIMs to source. Samples with anomalous values of KIMs close to a circular- to ellipsoid-shaped magnetic signature may suggest proximity to a potential source.
- The presence of chrome-diopside and olivine also suggest proximity to a source.
- Thorough mineralogical and petrological work on local igneous rocks should be undertaken.
- Structural data may prove useful as several anomalous sites occur at intersections of dikes and lineaments or along fault-controlled zones. Structural data from remote sensing images could help localize targets for kimberlite prospecting.

References

Boland, A.V. and Ellis, R.M. 1989. Velocity structure of the Kapuskasing uplift, northern Ontario, from seismic refraction studies; Journal of Geophysical Research, v.94, no.B6, p.7189-7204.

Kaminsky, F.V., Shchukin, V.S. and Istomine, V.A. 1997. Report on the 1997 field sampling for diamonds, the Whitefish Lake area, Ontario, Wawa–Vancouver, assessment file AFRI# 42C01NE2003, 12p.

Kaminsky, F.V., Sablukova, L.I., Dyachkova, I.N., Kolesnikova, T.I., Shcherbakova, T.E., Sablukov, S.M., Shpanov V.E., Ilupin, I.P. and Shcherbakova. A., 1999a. A. Study of panned samples from the Whitefish Lake area, Ontario: 1998 Field season. Moscow–Vancouver, assessment file AFRI# 42C01NE2003, 42p.

——— 1999b. Study of panned samples from the Kapuskasing areas, Ontario: 1998 Field season, Part 1: Kap-South area; compiled for Canabrava Diamond Corporation, Moscow–Vancouver, assessment file AFRI# 42G02NE2002, 92p.

Morris, T.F. 1992. Quaternary geology of the Wawa area; Ontario Geological Survey, Open File Map 192, scale 1:50 000.

Morris, T.F., Crabtree, D. and Pianosi, S. 1997. Results of modern alluvium sampling for kimberlite indicator minerals, Kinniwabi Lake area, northeastern Ontario; Ontario Geological Survey, Open File Report 5956, 72p.

Morris, T.F., Murray, C. and Crabtree, D. 1994. Results of overburden sampling for kimberlite heavy mineral indicators and gold grains, Michipicoten River–Wawa area, northeastern Ontario; Ontario Geological Survey, Open File Report 5908, 69p.

Stephenson, D.M., Morris, T.F. and Crabtree, D.C. 1999. Kimberlite, base metal and gold exploration targets based upon heavy mineral data derived from surface materials, Opasatika Lake area, northeastern Ontario; Ontario Geological Survey, Open File Report 5982, 59p.

Sage, R.P. 1994. Geology of the Michipicoten greenstone belt; Ontario Geological Survey, Open File Report 5888, 592p.

Trautman, R., Griffin, B.J. and Scharf, D. 1998. Microdiamonds; Scientific American, v.279, no.2, p.82-87.

HIGHLIGHTS

- **Exploration and development of critical minerals are a priority to ensure long-term stability of supply chains of these resources**
- **31 critical mineral occurrences are open for staking in the Sault Ste. Marie District**

Critical Mineral Occurrences in Sault Ste. Marie District

Ontario's diverse and complex geology offers tremendous opportunity for critical mineral exploration and development (Ontario's Critical Minerals Strategy 2022–2027, www.ontario.ca/page/critical-minerals [accessed October 17, 2022]). Critical minerals (*see* Ontario's list of critical minerals, www.ontario.ca/page/critical-minerals#section-1 [accessed October 17, 2022]) are naturally scarce and there is a growing reliance on such minerals by nearly all industries because these minerals cannot be easily replaced by other materials. Moreover, increasing geopolitical uncertainties and trade policies make it crucial to identify new sources, increase the exploration and development, and establish long-term stable supply chains of these resources (Emsbo, Lawley and Czarnota 2021).

In this article, a list is compiled from the Ontario Mineral Inventory (OMI) database (Ontario Geological Survey 2022; *see also* www.geologyontario.mndm.gov.on.ca/omi_description.html) of 31 occurrences of critical minerals that are available for mineral exploration land claim registration in the Sault Ste. Marie District (Table 1; Figure 1). Eighteen occurrences are for copper as a primary commodity (associated with other critical and noncritical minerals as secondary commodities), 8 are for uranium (2 associated with thorium), 2 for molybdenum, and 1 each for lead, zinc and tungsten. General geology of the occurrences, previous exploration work and noteworthy assay results are indicated in Table 1.

The critical mineral occurrences were identified by selecting all the available OMI locations that are currently open for claim registration. Both the primary and secondary commodities are listed although discretionary occurrences were omitted in this compilation. Users are recommended to consult with Mining Lands, Ministry of Mines (MINES), or use the Mineral Lands Administration System website (available at: www.lioapplications.lrc.gov.on.ca/MLAS/Index.html?viewer=MLAS.MLAS&locale=en-CA) for the latest claim availability of these occurrences.

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Maity, B.K. 2023. Critical mineral occurrences in Sault Ste. Marie District; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2022–2023, p.45-49.

Table 1. Available critical mineral occurrences in the Sault Ste. Marie District showing general geology and previous exploration work completed on the properties. Numbers in first column are keyed to Figure 1. Compiled *from* Ontario Mineral Inventory database (Ontario Geological Survey 2022).

No.	OMI *Assessment File No.*	Occurrence Name and *Township*	Primary (Secondary) Commodity	Geology	Previous Exploration Work	Longitude *Latitude*	UTM Zone NAD83
1	MDI41K16SE00041 *41K16SE0027*	Gratton *Gaudette*	Cu (Mo)	Quartz sulphide vein (335/35E) with pyrite, chalcopyrite and molybdenite hosted within hornblende gneiss in Archean tonalite suite.	Prospecting, trenching, mapping and assaying	-84.0559 *46.79966*	16
2	MDI41K16SE00043 *41K16SE0021; 41K16SW0374*	Meyer-Idziak *Gaudette*	Mo (Cu)	Quartz veins with disseminated sulphides and molybdenite and pegmatites in metasediments and granitic gneiss within Archean tonalite suite.	Geological mapping, diamond drilling, data compilation and interpretation	-84.0373 *46.79363*	16
3	MDI41K16SE00042 *41K16NE0002; 41K16SE0027*	Kristina *Gaudette*	Cu	Quartz chalcopyrite vein intruded within Keewatin granite-greenstone complex that was later intruded by Archean granite.	Geological mapping	-84.0784 *46.87648*	16
4	MDI41N15SE00007 *41N16NW0040; 41N16NW0002*	Palmgren Claims; Anjigami Lake Iron Formation *Nebonaionquet*	Fe, Cu, S	BIF (with pyrite bands) interbedded with mafic to intermediate tuffs and quartz-chlorite schist with quartz-carbonate alteration and sulphide mineralization in Archean Michipicoten greenstone belt.	Geological mapping, stripping, trenching, ground magnetic and airborne electromagnetic survey	-84.5353 *47.86668*	16
5	MDI41N01SW00037	Dick Lake *Norberg*	Cu	Quartz chalcopyrite vein in Archean granite in Batchawana greenstone belt.		-84.3657 *47.11317*	16
6	MDI41N01SW00035 *41N01SW0054*	Alcourt *Norberg*	Cu	Quartz chalcopyrite vein in shear zone (N65E) in metavolcanic rocks near contact with Archean granite in Batchawana greenstone belt.	Geological survey, trenching, magnetic and resistivity survey, assaying (0.3-2.1% Cu)	-84.4406 *47.07218*	16
7	MDI41N01SW00040 *SSMP-Olsen-04;* SSMP-Olsen-07; *SSMP-Olsen-13; SSMP-Olsen-29; SSMP-Olsen-27; SSMP-Olsen-29; SSMP-Olsen-32; SSMP-Olsen-34; SSMP-Olsen-18; SSMP-Olsen-22*	McCollough Lake *Olsen*	Cu	Archean volcanosedimentary rocks and ironstones in Batchawana greenstone belt.	Prospecting, line cutting, soil geochemistry, assaying, diamond drilling, scintillometer, ground magnetic and VLF–EM survey, data compilation	-84.3082 *47.1077*	16
8	MDI41K16SE00045	Wabosh Copper *Shields*	Cu	Quartz-chalcopyrite vein in Archean granite.		-84.1422 *46.80098*	16
9	MDI41N01NE00032	Martin Lake *Way White*	Cu (Pb)	Stringers and disseminated pyrite in felsic metavolcanic rocks in Batchawana greenstone belt.		-84.0978 *47.17848*	16
10	MDI41N01NE00031	Logan Lake *Way White*	Pb	Galena occurrences in Archean metavolcanic rocks in Batchawana greenstone belt.		-84.0201 *47.17059*	16

Table 1. *continued*

No.	OMI *Assessment File No.*	Occurrence Name and *Township*	Primary (Secondary) Commodity	Geology	Previous Exploration Work	Longitude *Latitude*	UTM Zone NAD83
11	MDI41J13SW00018 *41J13SW0006*	Marboy *Daumont*	Mo	Archean metasedimentary rocks containing molybdenite and disseminated to massive sulphide (pyrite, pyrrhotite, chalcopyrite, sphalerite) veins in east-trending shear zone.	Self-potential survey, diamond-drilling confirmed sulphide and molybdenite (0.25% over 1.5 ft) mineralization	-83.9641 *46.86933*	17
12	MDI41J06NW00026 *41J06NW0007*	Rockwin *Gould*	Cu	Quartz chalcopyrite vein cuts Gowganda sedimentary rocks, Cobalt Group, Huronian SG.	Diamond drilling	-83.3815 *46.47674*	17
13	MDI41J06NW00031 *41J06NW0003; 41J06NW0002*	Little Pickerel Lake *Grasett*	Cu	Quartz chalcopyrite vein within Gowganda sedimentary rocks of Cobalt Group, Huronian SG.	Diamond drilling, assaying (0.22% Cu over 0.5 feet, 3.25% Cu over 5.0 feet)	-83.3062 *46.48441*	17
14	MDI41J12NW00019 *41J12NW0102; 41K16SE0999; 41J12NW0103*	Mairs, H.J. *Hodgins*	Cu (Au)	Quartz vein (315/50N) with disseminated pyrite, chalcopyrite, sphalerite and galena along the contact of Archean granite and greenstone.	Overburden stripping, trenching, mapping, assaying (0.22% Cu to 4.08% Cu, up to 0.06 oz/ton Au)	-83.9865 *46.74386*	17
15	MDI41J13SE00019 *41J13SW0001*	Wabos Project *Hughes*	Cu (Pb)	Quartz veins with disseminated sulphides (pyrite, chalcopyrite, pyrrhotite and galena) in Archean granitic gneiss.	Diamond drilling	-83.7412 *46.80717*	17
16	MDI41O03SW00004	Aubinadong-North *Jessiman*	Cu (Ag)	Disseminated chalcocite and bornite in Archean granite and monzonite.		-83.3057 *47.12158*	17
17	MDI41J13NE00004	Gardiner, M.C. *Jollineau*	U	Pitchblende in veins and along joints in Archean granite.	Assay (0.01-2.78% U_3O_8)	-83.5976 *46.87505*	17
18	MDI41J11NE00012 *41J11NE0002; 41J10NW0020*	Blue Lake *Lecaron*	U	Pyrite mineralization in quartzite, argillite and arkose of Cobalt Group, Huronian SG	Geological mapping, diamond drilling	-83.0477 *46.67413*	17
19	MDI41J11NE00015	Duval Creek *Lecaron*	W (Fe)	Quartz vein in arkosic quartzite of Lorraine Formation, Cobalt Group, Huronian SG.		-83.0232 *46.6849*	17
20	MDI41J11NE00016	Kirkpatrick Lake - 1/ Sayer *Lecaron*	Cu (Fe, Ti)	Quartz carbonate vein with chalcopyrite along the contact of diabase and Lorrain Formation, Huronian SG.		-83.0854 *46.672*	17
21	MDI41O04SW00028	Loggers Lake-Northwest *Lunkie*	Cu	Pyrite and chalcopyrite in iron formation hosted in Archean felsic tuff.		-83.9585 *47.04375*	17
22	MDI41J07SW00019 *41J07SW0056; 41J07SW0162; 41J07SW0057; 41J07SW0060; 41J07SW0070*	Black Lake Occurrence *Mack*	U	Sheared argillite (radioactive) and quartz arenite of Lorrain Formation, Huronian SG.	Geological mapping, pitting, radiometric survey, assays (up to 0.24% U_3O_8)	-82.8822 *46.27875*	17

Table 1. *continued*

No.	OMI *Assessment File No.*	Occurrence Name and *Township*	Primary (Secondary) Commodity	Geology	Previous Exploration Work	Longitude *Latitude*	UTM Zone NAD83
23	MDI41J07SW00016 *41J07SW0050*	Emerald Lake *Mack*	Ni, Cu, Ag	Disseminated pyrite, pyrrhotite and chalcopyrite chloritized and sheared diabase intruding quartz arenite, Lorrain Formation, Huronian SG.	Prospecting, trenching, magnetic, electromagnetic, diamond drilling, assaying (0.027-1.25% Cu, 0.06-0.15% Ni, 0.11-0.72 oz/t Ag)	-82.8556 *46.29693*	17
24	MDI41J06SE00060	Copper Reef *Montgomery*	Cu	Sulphide magnetite bands parallel to limestone bedding in Bruce Formation, Huronian SG.		-83.1998 *46.35266*	17
25	MDI41J06NE00054 *41J06NE0037; 41J06NE9389*	RidgeField *Nouvel*	Cu (Au)	Quartz carbonate vein with chalcopyrite stringers in Gowganda Formation, Cobalt Group, Huronian SG.	Geological surveys, trenching, self potential survey, diamond drilling, assaying (0.05-1.02% Cu)	-83.1696 *46.4749*	17
26	MDI41J10NE00025 *41J10NE0002; 41J10NE0010*	Inspiration *Piche*	U	Radioactive conglomerate and quartzite containing monazite in Lorrain Formation, Huronian SG.	Data compilation, diamond drilling, assaying (0.01% U_3O_8)	-82.5494 *46.65296*	17
27	MDI41J10NE00030 *41J10NE0009*	Consolidated Golden *Piche*	U, Th	U and Th mineralization and hematitization in conglomerate, Lorrain Formation, Huronian SG.	Geological and ground radiometric survey, mapping	-82.5508 *46.65976*	17
28	MDI41J10NE00024 *41J10NE0031; 41J10NE0030; 41J10NE0021; 41J10NE0032*	Grey Trout - Blue Sky *Sagard*	U, Th	U and Th mineralization and hematitization in quartz pebble conglomerate, Lorrain Formation, Huronian SG.	Geological survey, trenching, diamond drilling, ground magnetic and radiometric survey, assaying (0.01-0.02% U_3O_8, 0.02-0.13% ThO_2)	-82.7153 *46.65081*	17
29	MDI41J10NE00026 *41J10NE0019; 41J10NE0020; 41J10NE0013*	Rottier Lake *Viel*	U	U mineralization in ferruginous feldspathic conglomerate, Lorrain Formation, Huronian SG.	Geological survey, diamond drilling, airborne magnetic and electromagnetic survey	-82.6729 *46.66702*	17
30	MDI41J12NW00018 *41J12NW0001*	Byrne Group *Whitman*	U	Rusty carbonatized shear zone with U mineralization in Archean Ramsay–Algoma granite.	Trenching, diamond drilling, assays (0.05% U_3O_8)	-83.889 *46.74373*	17
31	MDI41J12NW00021 *41J13SW9491*	Glendale *Whitman*	Zn	Rusty shear zone with sphalerite stringers in Archean Ramsay–Algoma granite.	Trenching	-83.889 *46.74373*	17

Abbreviations: OMI, Ontario Mineral Inventory; Au, gold; BIF, banded iron formation; Cu, copper; Fe, iron; Mo, molybdenum; NAD, North American Datum; Ni, nickel; Pb, lead; SG, Supergroup; Ti, titanium; Th, thorium; U, uranium; UTM, Universal Transverse Mercator; VLF-EM, very low frequency electromagnetic; W, tungsten; Zn, zinc.

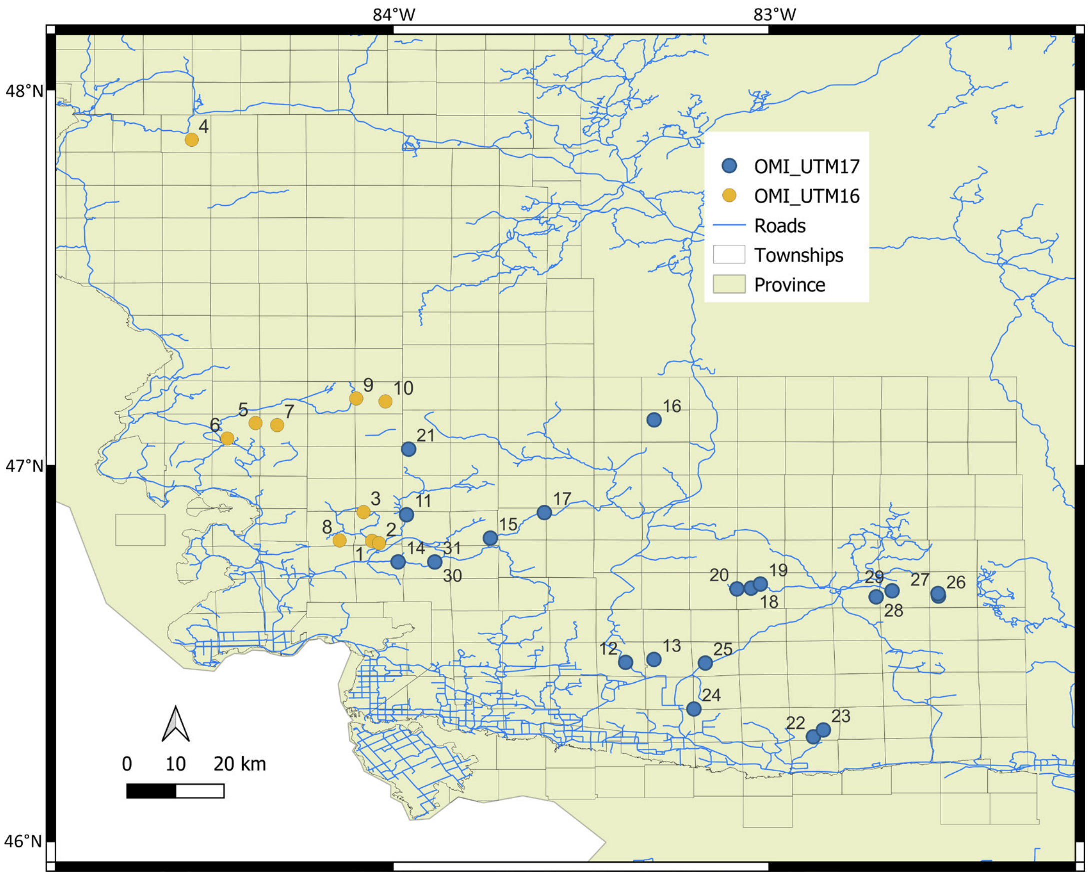

Figure 1. Available critical mineral occurrences in the Sault Ste. Marie District taken from the OMI database (current to October 17, 2022). Numbers next to OMI locations (yellow and blue dots) are keyed to Table 1.

References

Emsbo, P., Lawley, C. and Czarnota, K. 2021. Geological surveys unite to improve critical mineral security; Eos, v.102. https://doi.org/10.1029/2021EO154252 [website accessed on October 14, 2022].

Ontario Geological Survey 2022. Ontario Mineral Inventory; Ontario Geological Survey, Mineral Deposit Inventory, online database, October 2022 update. https://www.geologyontario.mndm.gov.on.ca/omi_description.html

HIGHLIGHTS

- **Possible high critical-element composition of banded iron formation in Timmins RGP District**
- **High V, Ag, Mn, Zn, Au and Cu in some samples**

Looking at Banded Iron Formations with a New Lens

Introduction

Banded iron formations (BIF) are layered chemical sediments comprising alternative layers of iron and chert. Banded iron formations are the main source of iron ore and have a much higher reserve and total production than ironstone and bog iron ore worldwide (Robb 2020). Banded iron formations are most common among Precambrian sedimentary successions, generally lack direct relationships with volcanic rocks, and vary in age from 3500 to 3000 Ma and 2500 to 2000 Ma in the Superior Province (Bekker et al. 2010). In most BIFs, iron is commonly found as an oxide (magnetite or hematite), carbonate (siderite), silicate (greenalite and minnesotaite) or sulphide (pyrite).

In 2020, Canada was the eighth-largest iron ore producer in the world, with 54.2 Mt of ore production. Most of the ore was mined in Quebec (56.4%), Newfoundland and Labrador (37.4%), and Nunavut (9%) (www.nrcan.gc.ca/our-natural-resources/minerals-mining/minerals-metals-facts/iron-ore-facts/20517).

Banded Iron Formation in Timmins District

Banded iron formations commonly occur in many townships within the Timmins Resident Geologist Program (RGP) District and have been associated with gold mineralization in both Timmins and Sault Ste. Marie RGP districts. However, the trace-element composition of these rocks is poorly understood. The government of Ontario introduced its final list of critical minerals in 2022. Several elements from the list can be associated with and found in BIFs, including, but not limited to, Zn, Ag, Au, Cr, Mn, Ni, V and Ti.

An assessment report from 2018 shows work in Musgrove Township where 5 rock samples were examined and assayed from BIFs on the K-2 property (Henriksen 2018; Figure 1). All samples are described as oxide iron formation and are magnetic. More importantly, a few trace-element values are more than 3 times the average upper continental crust values. Generally, geologists use the upper continental crust's average chemical composition to examine an elemental enrichment. More precisely, an element concentration is considered anomalous if the value is twice the average. Table 1 shows selected values from the assessment work filed for the K-29 property.

In this specific area, 2 of the 5 samples have anomalous values for Au, Ag, Cu, Cd, Zn, Mn and V (*see* Table 1). However, it is important to know if these values are comparable to known deposits. For example, the worldwide V_2O_5 grade varies between 0.10 to 1.51% in veneniferous

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Azadbakht, Z. 2023. Looking at banded iron formations with a new lens; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2022–2023, p.50-52.

titanomagnetite (VTM) deposits (Kelley et al. 2017). Another example would be the Kamiskotia Gabbroic Complex, where V_2O_5 values vary from 0.058 to 0.16% (Bousquet 2020). The sample (E-15872) from the K-29 property has the V_2O_5 ratio of 0.19%.

Another important factor that contributes to the economic value of a deposit is the host mineral for the elements of interest (i.e., critical elements or minerals, in this case). Unfortunately, trace elements cannot be economically extracted from all minerals because of metallurgical limitations. Therefore, it is important to know which minerals host the critical elements and if they can be recovered to acceptable grades.

Table 1. Selected trace-element compositions of 2 samples (E-15871 and E-15872) from the K-29 property in Musgrove Township (*from* Henriksen 2018). Average upper continental crust values are *from* Taylor and McLennan (1995).

Element	Unit	Average upper continental value	E-15871	Ratio	E-15872	Ratio
Au	ppb	1.8	54	30	12	7
Ag	ppb	50	1500	30	9100	182
Cu	ppm	25	312	12	162	6
Cd	ppm	98	1600	16	-	
Zn	ppm	71	870	12	362	5
Mn	ppm	600	2680	4	4520	8
V	ppm	60	46		1050	17

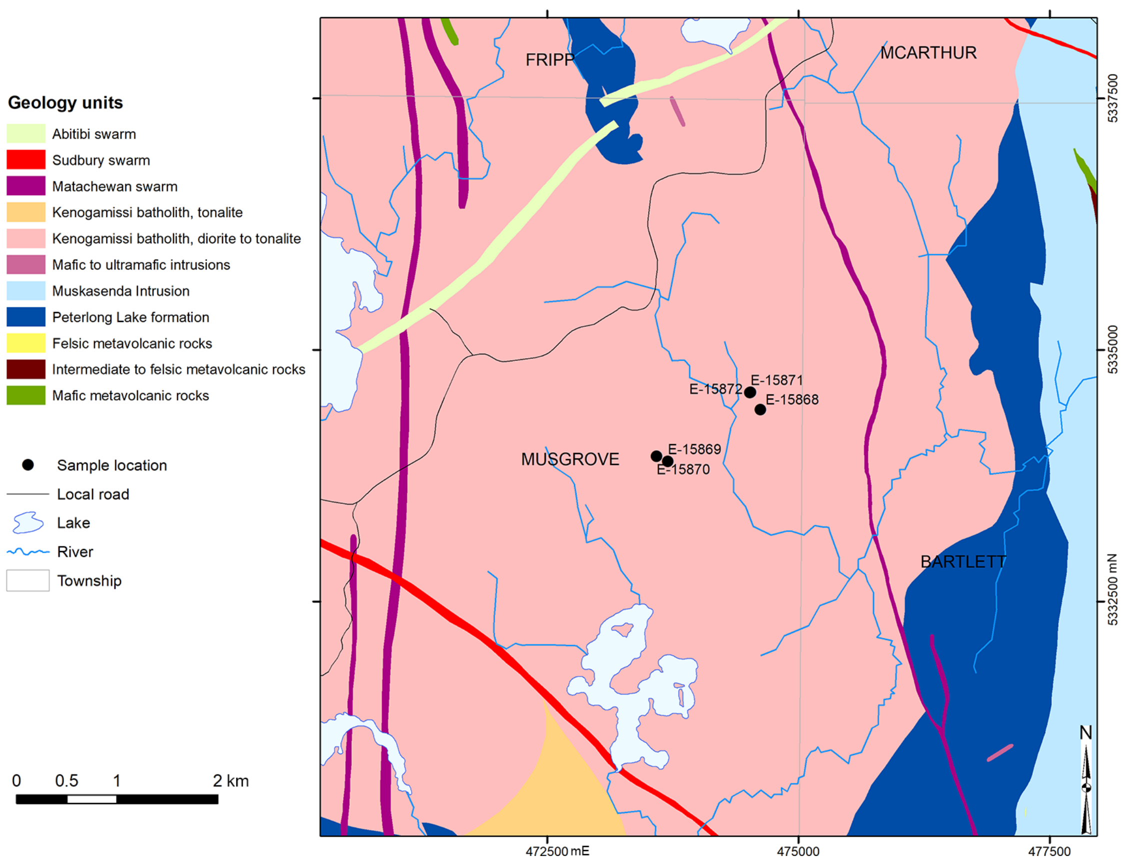

Figure 1. Geological map of Musgrove Township showing sample locations (*from* Henriksen 2018) on the K-29 property (geology *from* Ontario Geological Survey 2011). Universal Transverse Mercator (UTM) co-ordinates are provided using North American Datum 1983 (NAD83) in Zone 17.

Trace element composition, economic value and host minerals are unknown for many of the BIFs worldwide. It is also unclear which type of BIF (i.e., oxide, sulphide, silicate or carbonate) has a more prominent critical mineral potential. The example above shows the importance of studying these simple yet complicated deposits to understand and examine their full economic potential.

Recommendations

- Re-examine BIF samples from the Timmins Districts to collect and study trace-element compositions, including V, Ti, Cr, Ag, Ni, Au, Cu, Cd, Zn and Mn. Inductively coupled plasma mass spectrometry (ICP–MS) can be used to complete this task.
- Identify the host mineral for the critical elements.

References

Bekker, A., Slack, J.F., Planavsky, N., Krapež, B., Hofmann, A., Konhauser, K.O. and Rouxel, O. 2010. Iron formation: The sedimentary product of a complex interplay among mantle, tectonic, oceanic, and biospheric processes; Economic Geology, v.105, p.467-508.

Bousquet, P. 2020. Kamiskotia Gabbroic Complex: Looking at it under a different lens; *in* Report of Activities 2019, Resident Geologist Program, Timmins Regional Resident Geologist Report: Timmins and Sault Ste. Marie Districts, Ontario Geological Survey, Open File Report 6366, p.42-44.

Henriksen, G.N. 2018. Report on the soil geochemistry sampling survey, prospecting, mapping and sampling for Mr. Richard Stroz on the K-29 property in Musgrove Township in the Timmins area, Ontario NTS 42A3; Timmins Resident Geologist's office, Assessment File # 20000016278, 51p.

Kelley, K.D., Scott, C.T., Polyak, D.E. and Kimball, B.E. 2017. Vanadium; Chapter U *in* Critical Mineral Resources of the United States—Economic and Environmental Geology and Prospects for Future Supply, Professional Paper 1802, p.U1-U36. https://doi.org/10.3133/pp1802U

Ontario Geological Survey 2011. 1:250 000 scale bedrock geology of Ontario; Ontario Geological Survey, Miscellaneous Release—Data 126–Revision 1.

Robb, L.J. 2020. Introduction to ore forming processes; Wiley-Blackwell, Oxford, 496p.

Taylor, S.R and McLennan, S.M. 1995. The geochemical evolution of the continental crust; Reviews in Geophysics, v.33, no.2, p.241-265. https://doi.org/10.1029/95RG00262.

HIGHLIGHTS

- **A different approach to exploring for cobalt in the Huronian basin**
- **Archean-hosted cobalt deposits**
- **Exploring for gold – and cobalt too!**

Archean-hosted Cobalt in the Elk Lake, Gowganda and Shining Tree Areas

In keeping within a critical minerals theme that appeared in last year's Recommendation for Exploration (Chadwick 2022), the author was inspired by an article that discussed the regional and local controls on Archean-hosted cobalt mineralization at the McAra deposit, located southeast of Shining Tree in the Kirkland Lake District (Hendrickson 2020). The aim of this Recommendation for Exploration is to consider the potential for any additional McAra-like, Archean-hosted cobalt mineralization elsewhere in the Elk Lake, Gowganda and Shining Tree areas, and to hopefully provide some guidance as to where in the region to look for it.

McAra Deposit Model: An Example of Archean Rock-hosted Cobalt Mineralization

Historically, cobalt has been mined as a by-product, along with silver, within five-element (silver-cobalt-nickel-bismuth-arsenic) veins at the Cobalt and Gowganda camps, which were mostly hosted along the Nipissing gabbro–Huronian sediment contact or the Archean basement unconformity (Petruk 1971; Andrews et al. 1986). The McAra cobalt deposit is hosted in an Archean inlier to the Paleoproterozoic Huronian basin and is estimated to contain approximately 2.4 million pounds of cobalt at an average grade of 1.25% (Page and Ilieva 2018). In contrast to veins at the Cobalt and Gowganda camps, the McAra deposit is hosted primarily within Archean-age mafic volcanic rocks, sedimentary rocks and a mafic-siliciclastic massive sulphide deposit, and reports higher grades of cobalt (Hendrickson 2020). Hendrickson (2020) goes into great detail in describing deposit-scale geochemistry, and a detailed review and assessment of all available geophysical data sets covering the entire Huronian basin was also undertaken. Hendrickson (2020) concludes that the cobalt zone at McAra and the five-element veins share a similar metal assemblage and were likely deposited from similar fluids, possibly derived from Archean-hosted stratigraphy. Basin brines in the Paleoproterozoic were interpreted to have leached cobalt from Archean-age rocks and subsequently redeposited it along northwest-striking, synvolcanic, crustal-scale faults. Geophysical data interpretations and observations from field mapping suggest that the McAra deposit is located on the margin of a subbasin that contains an 80 km^2 Nipissing sill, which may have originally overlain the deposit and been a hydrologic seal during mineralization (Hendrickson 2020).

An Alternate Approach

For the purpose of this article, the author had selected key observations as regards the geological and structural components from the McAra study

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Chadwick, P.J. 2023. Archean-hosted cobalt in the Elk Lake, Gowganda and Shining Tree areas; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2022–2023, p.53-55.

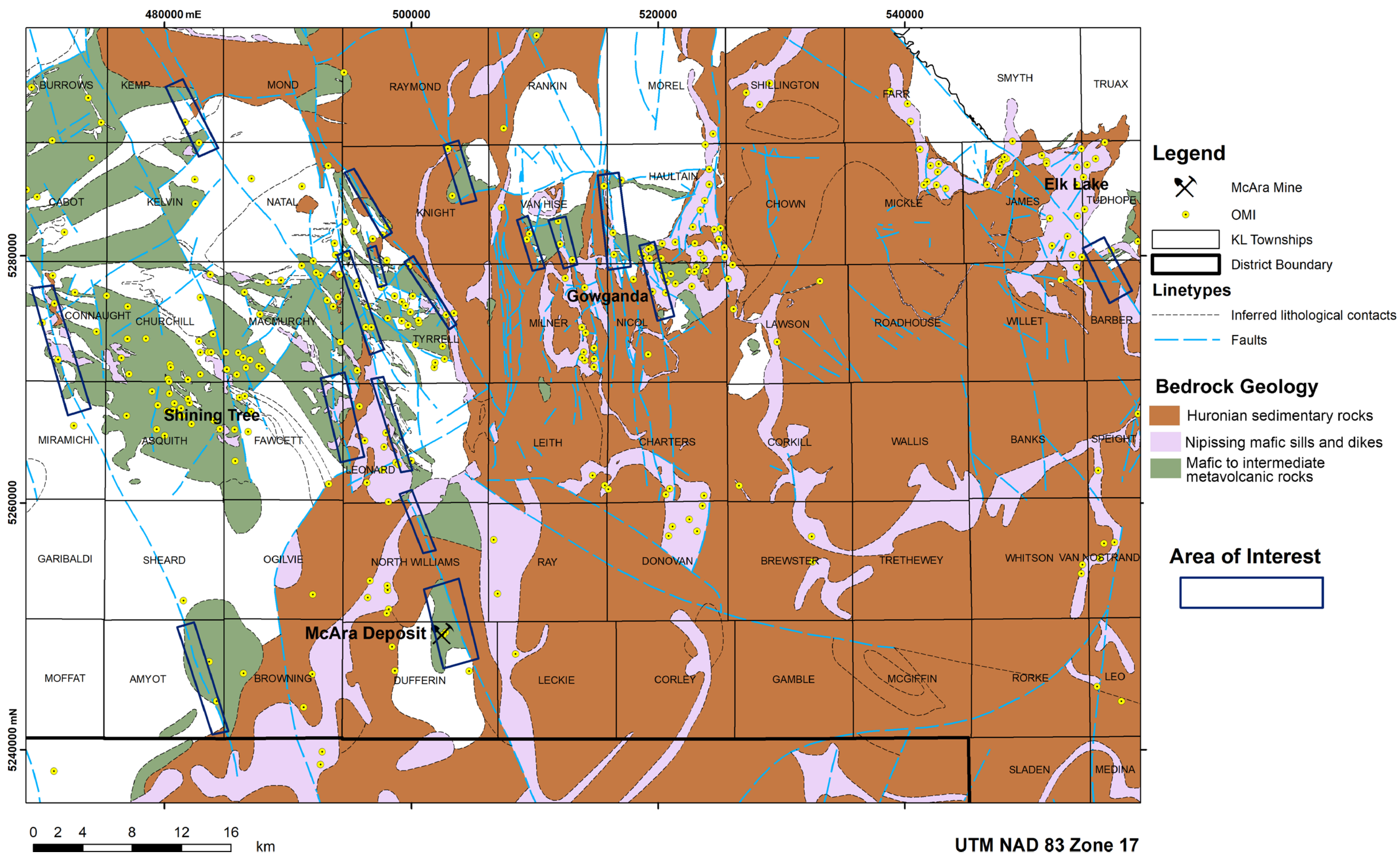

Figure 1. A filtered geological map of the Elk Lake, Gowganda and Shining Tree areas (geology *from* Ontario Geological Survey 2011), showing Huronian sedimentary rocks, Nipissing diabase and Archean mafic metavolcanic rocks only. Key geological structures, Ontario Mineral Inventory locations (Ontario Geological Survey 2022) and proposed areas of interest are also shown. Abbreviations: KL, Kirkland Lake; OMI, Ontario Mineral Inventory.

and used these to identify possible areas of interest or areas that appear to have a similar geological and structural setting to that noted at McAra. These include the following:

- Archean-age mafic to intermediate metavolcanic host rocks,
- close proximity to exposed Huronian-age sediments and Nipissing mafic sills, and
- proximal to northwest-striking, regional-scale faults.

Areas of Interest for Future Exploration

Figure 1 represents a filtered geological map of the Elk Lake, Gowganda and Shining Tree areas, showing Huronian sediments, Nipissing diabase sills and dikes and Archean mafic metavolcanic rocks, with all other rock types intentionally omitted. Major geological structures are also shown in addition to Ontario Mineral Inventory locations (Ontario Geological Survey 2022).

The locality of the McAra deposit is clearly shown in Figure 1 and is seen centred within an Archean metavolcanic inlier in contact with Huronian basin sedimentary rocks and proximal to a northwest-striking fault. Remnant exposures of Nipissing diabase can also be observed bounding the deposit. Using this geological setting as a template, the author simply highlighted, with blue rectangles, other areas within the region that appear to share a similar geological setting.

Whilst Archean metavolcanic rocks make ideal targets for gold exploration, especially in areas that are proximal to dominant geological structures, the possibility of coexisting five-element (silver-cobalt-nickel-bismuth-arsenic) vein mineralization should not be overlooked.

References

Andrews, A.J., Owsiacki, L., Kerrich, R. and Strong, D.F. 1986. The silver deposits at Cobalt and Gowganda, Ontario. I: Geology, petrography, and whole-rock geochemistry; Canadian Journal of Earth Sciences, v.23, no.10, p.1480-1506.

Chadwick, P.J. 2022. Looking for cesium in the northern parts of the Kirkland Lake District; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2021–2022, p.24-29.

Hendrickson, M.D. 2020. Regional and local controls on Archean rock-hosted cobalt mineralization at the McAra deposit, southern Superior Province, Ontario, Canada; Canadian Journal of Earth Sciences, v.57, p.1447-1462.

Ontario Geological Survey 2011. 1:250 000 scale bedrock geology of Ontario; Ontario Geological Survey, Miscellaneous Release—Data 126–Revision 1.

——— 2022. Ontario Mineral Inventory; Ontario Geological Survey, Ontario Mineral Inventory, online database.

Page, M. and Ilieva, T. 2018. Cobalt Exploration Project SE Ontario and SW Quebec, Canada, prepared for Battery Minerals Resources Ltd. by Exploration Services International; NI 43-101 Technical Report, filed June 19, 2018 with SEDAR®, *see* SEDAR Home Page, 411p.

Petruk, W. 1971. General characteristics of the deposits; The Canadian Mineralogist, v.11, no.1, p.76-107.

HIGHLIGHTS

- **Minimal historical production in the area**
- **Mineralized silver-cobalt veins are strongly focused within well-developed structures**
- **Gold and base metal mineralization in Archean metavolcanic rocks in association with silver-cobalt-nickel mineralization**

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Polymetallic Silver-Cobalt-Nickel-Copper-Gold Potential in the Elk Lake Area

The Elk Lake area (referred to herein as "the area") is centred on James Township, approximately 52 km southwest of the town of Kirkland Lake. The area is underlain by Archean mafic, intermediate to felsic metavolcanic rocks generally represented by basaltic, andesitic and dacite flows, tuffs and breccia. This metavolcanic suite is intruded by massive to foliated Archean granitic rocks of the Round Lake batholith. Cobalt Group (Huronian Supergroup) sedimentary rocks (siltstone, argillite, sandstone, quartz sandstone, conglomerate), which represent approximately 75% of surface rock in the area, unconformably overlie the older metavolcanic and granitic rocks (MacKean 1967). Younger Nipissing diabase dikes and sills intrude all rocks in the Elk Lake area (Figure 1).

With respect to geological structures, faults and joints seen in the bedrock are numerous and the presence of many faults is reflected in the terrain (Roed 1979). There are several northwest- and northeast-trending faults in the map area but the most prominent is the northwest-trending Montreal River fault (MRF). North-trending faults are limited to James and Willet townships.

Although there exists a good number of mineral occurrences, there has been very minimal documented historical production in the area. Some of the more important mineral commodities categorized as prospects and developed prospects are documented in Table 1. In August of 2020, Battery Mineral Resources Corporation completed 6 diamond-drill holes totaling 690 m in the Elk Lake area. The company reported that mineralized silver-cobalt veins are strongly focused within well-developed structures, and that mineralization is dominated by copper-gold-silver-cobalt-rich calcite and/or quartz veins which trend parallel to dominant faulting, fracturing or jointing (Ploeger, Doyle and Hicks 2021).

Recommendation for Exploration

The Elk Lake area should not be overlooked. Gold and base metal mineralization in Archean metavolcanic rocks is in association with silver-cobalt-nickel mineralization within Cobalt Group sedimentary rocks. This association presents a high propensity for polymetallic mineralization in the area. In the exploration for polymetallic silver-cobalt-nickel-copper-gold mineralization in the Elk Lake area, a comprehensive primary prospecting and geochemical soil sampling program could help in establishing new mineralized zones. It is likely that secondary faults emanating from the MRF could have focused hydrothermal fluid flow, depositing gold and base metal mineralization at sites where they

Suma-Momoh, J. 2023. Polymetallic silver-cobalt-nickel-copper-gold potential in the Elk Lake area; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2022–2023, p.56-58.

Table 1. Selected mineral properties in the Elk Lake area. Numbers in first column are keyed to Figure 1.

No.	Property Name	Commodities	Township	OMI	Mineral Status
1	Roy	silver, copper, nickel, cobalt, gold	Farr	MDI41P16SW00003	DPWR
2	Ethel Copper	silver, copper, gold	James	MDI41P09NW00014	DPWR
3	Beacon Consolidated Mines Ltd.	silver, cobalt	James	MDI41P09NW00037	P
4	Beaver Auxiliary Mines Company Ltd.	silver, copper, nickel, cobalt, lead	James	MDI41P09NW00038	P
5	Devlin Mining Company Ltd.	silver	James	MDI41P09NW00039	P
6	Moose Horn Mines Ltd.	silver, cobalt	James	MDI41P09NW00041	P
7	Mother-Lode	silver, copper	James	MDI41P09NW00042	P
8	McManus Group	silver, copper, nickel, cobalt	James	MDI41P09NW00043	P
9	Shane-Darragh	silver, copper, nickel, cobalt	Mickle	MDI41P09NW00006	DPWR
10	B.L. Morrison	silver, nickel, cobalt	Mickle	MDI41P09NW00010	DPR
11	G.S. Welsh	silver, copper, nickel, cobalt, lead	Mickle	MDI41P09NW00035	Prospect
12	Paramount Copper Prospect	silver, copper, cobalt	Tudhope	MDI41P09NW00044	Prospect
13	Lucky	silver, cobalt	Willet	MDI41P09NW00002	DPWR

Source: Ontario Mineral Inventory (2022); Abbreviations: OMI=Ontario Mineral Inventory, DPR=Developed Prospect with Reported Reserves or Resources, DPWR=Developed Prospect Without Reported Reserves or Resources, P=Prospect.

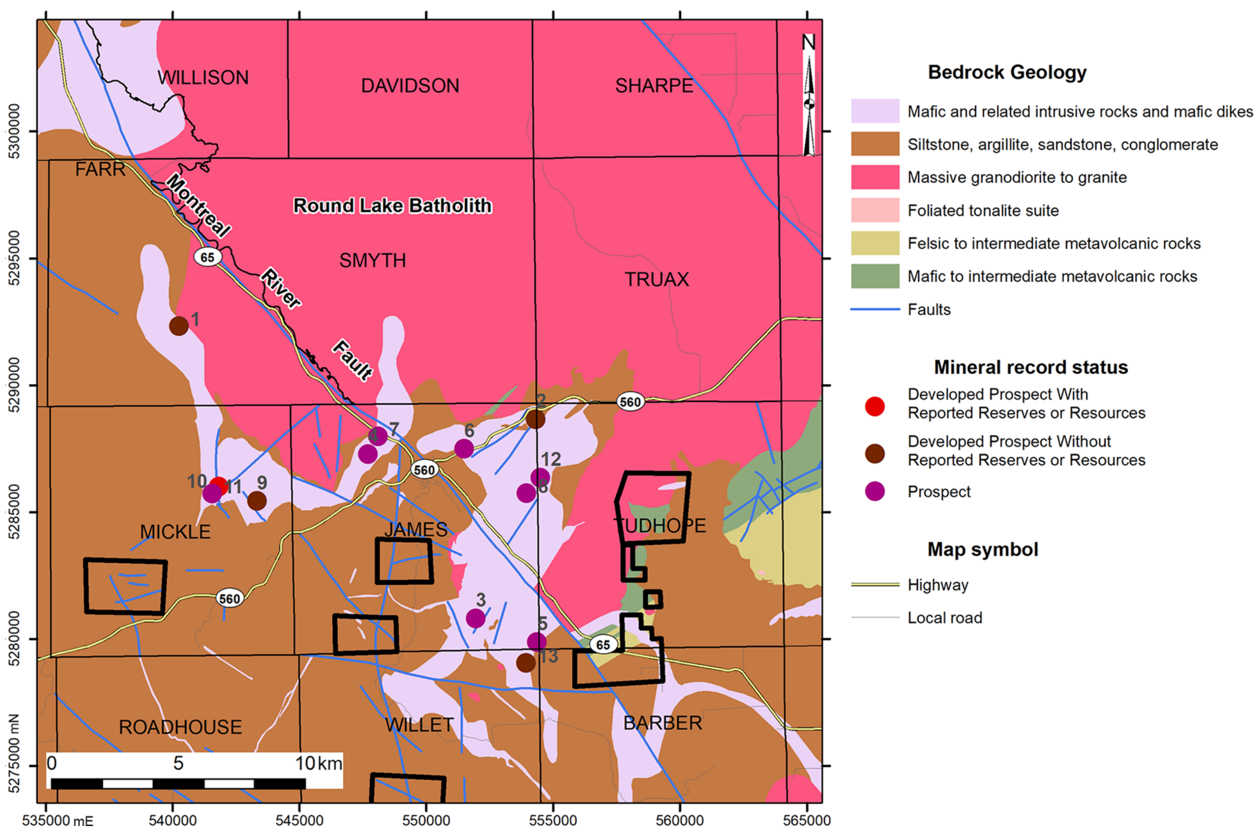

Figure 1. Geological map of the Elk Lake area showing location of selected significant mineral properties (*from* Ontario Geological Survey 2022). The areas outlined in black are crown land open for claim registration. Numbers are keyed to Table 1. Geology *from* Ontario Geological Survey (2011). Universal Transverse Mercator (UTM) co-ordinates are provided using North American Datum 1983 (NAD83) in Zone 17.

crosscut and truncate one another (in central and southern James Township, northern Willet Township and southern Mickle Township). In addition, Andrews et al. (1986) reported that silver-cobalt-nickel vein systems occur in faults and fault-related fracture systems hosted by Huronian Supergroup sedimentary rocks, Nipissing diabase sills and Archean basement rocks. Based upon these premises, it is therefore recommended that a geophysical program consisting of modern induced polarization (IP) and versatile time domain electromagnetic (VTEM) exploration techniques, which have the capacity for deep overburden penetration and detecting buried targets, be conducted, followed by diamond drilling. Figure 1, keyed to Table 1, illustrates the locations of polymetallic mineral potential that are open for claim registration at the time of writing this report.

References

Andrews, A.J., Owsiacki, L., Kerrich, R. and Strong, D.F. 1986. The silver deposits at Cobalt and Gowganda, Ontario. I: Geology, petrography, and whole-rock geochemistry; Canadian Journal of Earth Science, v.23, p.1480-1506.

MacKean, B.E. 1967. Geology of the Elk Lake area, District of Timiskaming; Ontario Department of Mines, Geological Branch, Open File Report 5006, 149p.

Ontario Geological Survey 2011. 1:250 000 scale bedrock geology of Ontario; Ontario Geological Survey, Miscellaneous Release—Data 126–Revision 1.

——— 2022. Ontario Mineral Inventory; Ontario Geological Survey, Ontario Mineral Inventory, online database.

Ploeger, F., Doyle, P. and Hicks, S. 2021. Drilling report on the Silverstrike area, Elk Lake property of Battery Mineral Resources Corp., James Township, Northeastern Ontario; Sault Ste. Marie District Geologist office, assessment file # 20000019384, 102p.

Roed, M.A. 1979. Elk Lake area (NTS 41P/NE), District of Timiskaming; Ontario Geological Survey, Northern Ontario Engineering Geology Terrain Study 83, 18p. Accompanied by Map 5020, scale 1:100 000.

HIGHLIGHTS

- **Gold mineralization is known to occur in the area of soda metasomatism in the Sudbury District, and has been considered to be modified IOCGs**
- **Researchers into metasomatic-iron-alkali-calcic systems have defined new alteration facies with associated mineralization types, including IOCG**

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Metasomatic Iron and Alkali-Calcic System in the Sudbury District

Soda (Na) metasomatism is widespread across the Huronian Supergroup in the Sudbury District (Schandl and Gorton 2007; Farrow 2016; Figure 1) and has been related to a potential modified iron-oxide-copper-gold system (IOCG; Corriveau 2007; Schandl and Gorton 2007; Farrow 2016). Gates (1991) recognized regionally albitized rocks extending from Bruce Mines, west of Sudbury, along the north shore of Lake Huron, to the Temagami area, northeast of Lake Wanapitei. Uranium-lead (U-Pb) geochronology indicates that the metasomatic albitization occurred in the Wanapitei Lake area at 1700±2 Ma (Schandl, Gorton and Davis 1994). Current research (Corriveau, Potter and Mumin 2022; Adlakha et al. 2022; and references therein) shows that such widespread soda metasomatism forms albitite corridors where the metasomatism is intense and where albitite is the first facies of a regular series of alterations produced by the upwelling of regional hypersaline fluid plumes as they evolve in temperature and composition. The sum of the alteration facies defines the metasomatic iron and alkali-calcic (MIAC) system. Iron-oxide alkali-calcic alteration (IOAA) facies are currently best understood but facies can precipitate iron-silicate, iron-carbonate, iron-sulphide or iron-poor variants. Distinct mineral deposit types are associated with the evolving alteration facies (Corriveau, Montreuil, Blein et al. 2022; Corriveau, Montreuil, Potter et al. 2022; Figure 2). Table 1 summarizes the minerals forming the suite of assemblages for the main alteration facies (1 to 5), along with the associated commodities (Corriveau, Montreuil, Potter et al. 2022). The new facies definitions and mineralization associations will delineate where a property is within the system and the type of mineralization that could be encountered. As the precipitation of the distinct facies behave like a chain reaction, the mapped progression of alteration facies can vector to the next facies and its potential mineralization, bearing in mind that tectonic disruption and overprinting are common.

In the Sudbury District, the Scadding deposit was the first deposit considered to be a modified IOCG (Schandl and Gorton 2007). Following the recognition that synmineralization iron minerals can be oxides, silicates, carbonates or sulphides, Montreuil, Corriveau, Bien et al. (2022) have reclassified Scadding as a metasomatic iron-gold deposit that precipitated at Facies 5 alteration under its low temperature Ca-Mg-Fe^{2+} end-member (LT Ca-Mg-Fe^{2+} *in* Table 1). The mineralization style for Facies 5 ranges from “hematite group IOCG deposits” at the low-temperature K-Fe end-member to metasomatic iron variants under the low temperature Ca-Mg-Fe±K alteration (*see* Figure 2). Other mineral exploration properties in the District are also being explored using an IOCG (MIAC) model, for example, the Aylmer IOCG, Cobalt Hill and Lake Zone occurrences.

Péloquin, A.S. 2023. Metasomatic iron and alkali-calcic system in the Sudbury District; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2022–2023, p.59-62.

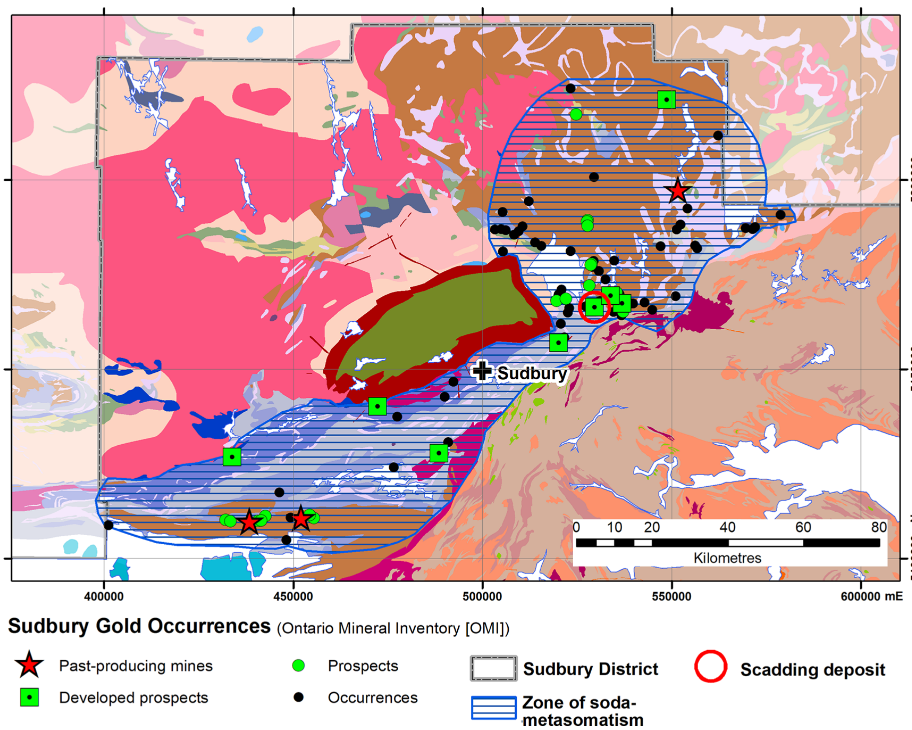

Figure 1. Sudbury District showing gold occurrences from the Ontario Mineral Inventory (Ontario Geological Survey 2022) and the area impacted by soda-metasomatism (*from* Farrow 2016). Geology *from* Ontario Geological Survey (2011).

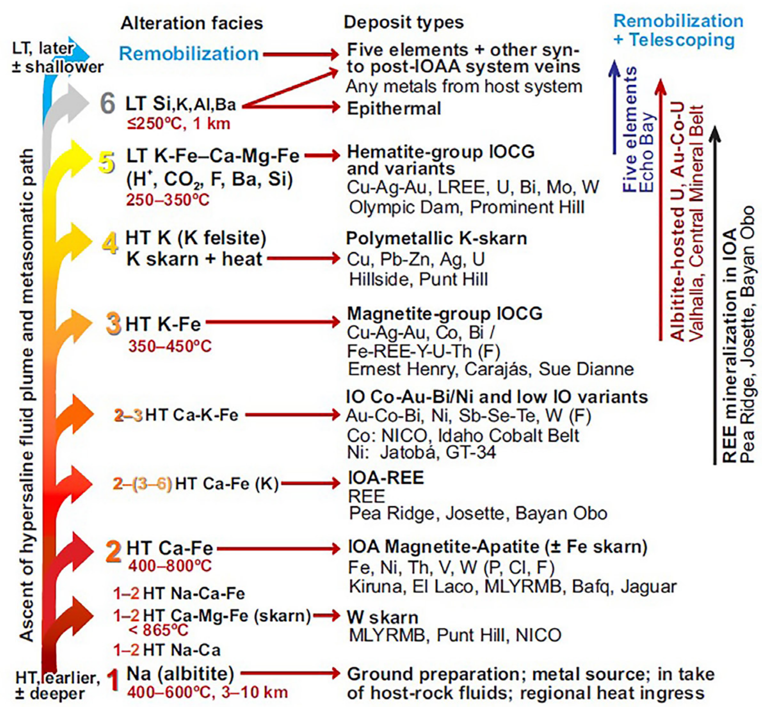

Figure 2. Metasomatic IOAA facies (1 to 6) related to MIAC systems and their related mineral deposit types. *From* Corriveau, Mumin and Potter (2022). Abbreviations: IOA=iron oxide apatite; IO=iron oxide; LT=low temperature; HT=high temperature; MLYRMB=Middle-Lower Yangtze River Metallogenic Belt; REE=rare earth elements.

Table 1. Main alteration phase mineralogy and metal associations. (Table simplified *from* Table 2 in Corriveau, Montreuil, Potter et al. 2022. For details, including examples for each mineralization type, refer to Corriveau, Montreuil, Potter et al. 2022).

Facies		Minerals		Element Enrichment		
		Major	Accessory to Major	Major Commodity	Economic Potential	Others
Facies 5	**LT Ca/Mg/Na/K/Si/H+/CO_2**	qtz c chl ab kfs ms		Au Co Cu Mo Re U Zn		
	LT Ca-Mg-Fe^{2+}	chl mag	ab amp ank dol	Au Cu	Bi Co U	Fe LREE Na Ni
	LT Ca-Mg-Fe^{3+}- (±F)	act adr aln chl ep hem hs	ank brt cal fl kfs ms	Ag Au Cu Pb U Zn	LREE	Ba F Fe S K Mn Sb Sn Sr Te W
	LT Si-Fe- (±Ba)	hem qtz	aln ank brt cal fl sd	Au Cu Fe	LREE U	Ba Fe Si
	LT K-Fe	chl hem ms sd	aln ank brt cal dol ep fl kfs qtz	Ag Au Cu Fe U	Co LREE Mo Pb Re W Zn	As Ba C Cd F K Mn P S Sb Se Sn Te W
Facies 4	**K-skarn**	aln cpx ep kfs	ank cal dol mag	None	Cu Mo Pb Zn	K Th U
	K felsite	kfs		None	None	Ba K Rb Th
Facies 3	**HT K-Fe (Kfs)**	kfs mag	bt cal chl	Ag Au Cu Fe U	Mo	Ba C F K Rb Mn P REE Sb Te Th V Zr
	HT K-Fe (Bt)	bt mag	amp grt kfs	Ag Au Co Cu Fe U	Mo Pd Pt	Ba C F K Rb Mn P REE Sb Te Th V Zr
Facies 2–3	**HT Ca-K-Fe**	amp bt kfs mag	ap cpx grt sd	Au Bi Co Cu Ni	Ag As Mo Sb Se Te W	Ba Ca K P Rb REE S Th U Y
Facies 2	**HT Ca-Fe**	amp mag	aln ap cpx ep qtz	Fe Ni P REE	Co V W	Ca Mg Th U
Facies 1–2	**Fe-skarn**	cpx grt mag	amp qtz	Fe W	REE Co Ni V	P Th U
	Skarn	cpx grt	aln amp cal chl dol mag phl		W	Fe
	HT Na-Ca-Fe	ab amp mag	ap cpx	None	Fe REE V	Na Ca P Th
Facies 1	**Na and Na-Ca**	ab scp (residual qtz)	amp cpx	None	Al	Ga Na Nb Ta Ti Zr

Abbreviations: ab=albite; adr=andradite; aln=allanite; amp=amphibole; ank=ankerite; ap=apatite; brt=barite; bt=Biotite; cal=calcite; c=carbonate; chl=chlorite; cpx=clinopyroxene; dol=dolomite; ep=epidote; Fe-dol= iron-dolomite: fl=fluorite; grt=garnet; hem=hematite; hs=hastingsite; kfs=K (potassium)-feldspar; LREE=light rare earth elements; LT=low temperature; mag=magnetite; ms=muscovite; phl=phlogopite; qtz=quartz; REE=rare earth elements; scp=scapolite; sd=siderite.

Recommendations for Exploration

The regional development of extensive albitite in association with intense low temperature Ca-Mg-Fe±K alteration and their wide variety of metal associations indicate the potential for MIAC system-related mineral deposits in the Sudbury District. However, it is the local or property-scale alteration facies, including those overprinting albitite, that will point to the type of mineralization that may be present. For each facies, alteration assemblages and mineral contents evolve markedly across an area, but each facies has a highly diagnostic suite of assemblages that distinguish it from the other facies. The facies approach of mapping alteration facies, rather than single minerals or spatial associations of minerals, facilitates the interpretation of the system as defined in Table 1.
Iron is a notable component of the alteration, although low-iron alteration types may occur. Lithologies should, therefore, be tested for their magnetism, as metasomatic magnetite is common. However, the iron mineral can be oxides, silicates, carbonates or sulphides, and may not be magnetic. For example, chloritization is a common form of iron alteration in the District. The presence of structures (faults or folds), zones of higher deformation, or zones of changes in rock competency (such as contacts) should be noted, as they may have been the conduits for the fluids. Hydrothermal brecciation is commonly associated with the alteration. Geochemistry is also a useful tool to define alteration facies. A "barcode" method for the MIAC system, using molar proportions of Na-Ca-Fe-K-Mg, has been developed (Corriveau, Montreuil, Blein et al. 2022). When doing multi-element analyses for this purpose, 4-acid digestion is the preferred sample preparation method, and when available, a fusion method prior to dissolution is recommended. Aqua regia digestion will not fully dissolve these rocks and should be avoided.

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I wish to thank Louise Corriveau for all the work she and her colleagues have done under the NRCan Targeted Geoscience Initiative program, for so openly sharing her knowledge and for her insightful review of this document.

References

Adlakha, E., Corriveau, L., Neyedley, K., Conliffe, J. and Piette-Lauzière, N. (organizers) 2022. Metasomatic iron and alkali-calcic (MIAC) systems with IOCG and associated critical mineral deposits: Prospectivity of the Canadian Appalachian Orogen; Geological Association of Canada – Mineralogical Association of Canada – International Association of Hydrogeologists – Canadian National Committee – Canadian Society of Petroleum Geologists (GAC-MAC-IAH-CNC-CSPG) Annual Meeting, Workshop SCW-A1, Halifax, Nova Scotia, May 15–18, 2022.

Corriveau, L. 2007. Iron oxide copper-gold deposits: A Canadian perspective; *in* Mineral Deposits of Canada: A Synthesis of Major Deposit-Types, District Metallogeny, the Evolution of Geological Provinces, and Exploration Methods, Geological Association of Canada, Mineral Deposits Division, Special Volume 5, p.307-328.

Corriveau, L., Montreuil, J.-F., Blein, O., Ehrig, K., Potter, E.G., Fabris, A. and Clark, J. 2022. Mineral systems with IOCG and affiliated deposits: Part 2 – Geochemical footprints; *in* Mineral Systems with Iron Oxide Copper-Gold (IOCG) and Affiliated Deposits, Geological Association of Canada, Special Paper 52, p.158-202.

Corriveau, L., Montreuil, J.-F., Potter, E.G., Blein, O. and De Toni, A.F. 2022. Mineral systems with IOCG and affiliated deposits: Part 3 – Metal pathways and ore deposit model; *in* Mineral Systems with Iron Oxide Copper-Gold (IOCG) and Affiliated Deposits, Geological Association of Canada, Special Paper 52, p.205-245.

Corriveau, L., Mumin, H.A. and Potter, E.G. 2022. Mineral systems with iron oxide copper-gold (Ag-Bi-Co-U-REE) and affiliated deposits: Introduction and overview; *in* Mineral Systems with Iron Oxide Copper-Gold (IOCG) and Affiliated Deposits, Geological Association of Canada, Special Paper 52, p.1-26.

Corriveau, L., Potter, E.G. and Mumin, H.A. (eds) 2022. Mineral Systems with Iron Oxide Copper-Gold (IOCG) and Affiliated Deposits, Geological Association of Canada, Special Paper 52, 424p.

Farrow, D. 2016. Soda metasomatism as a possible iron oxide-copper-gold (IOCG) deposit indicator in the Sudbury District; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2016–2017, p.65-67.

Gates, B.I. 1991. Sudbury mineral occurrence study; Ontario Geological Survey, Open File Report 5771, 235p.

Montreuil, J.-F., Corriveau, L., Blein, O., Hofstra, A., Lisitsin, V., Schlegel, T., Mansur, E., Sappin, A.-A., Sparkes, G., Ehrig, K., Conliffe, J., Zhao, X., de Toni, A., Goad, R., Belperio, A. and Baldwin, G. 2022. Distribution of alteration facies, deposit types, metals, and critical minerals in metasomatic iron and alkali-calcic (MIAC) mineral systems; Workshop *at* Metasomatic Iron and Alkali-Calcic (MIAC) Systems with IOCG and Associated Critical Mineral Deposits: Prospectivity of the Canadian Appalachian Orogen, Geological Association of Canada – Mineralogical Association of Canada – International Association of Hydrogeologists – Canadian National Committee – Canadian Society of Petroleum Geologists (GAC-MAC-IAH-CNC-CSPG) Annual Meeting, Workshop SCW-A1, May 15–18, 2022.

Ontario Geological Survey 2011. 1:250 000 scale bedrock geology of Ontario; Ontario Geological Survey, Miscellaneous Release—Data 126–Revision 1.

——— 2022. Ontario Mineral Inventory; Ontario Geological Survey, Ontario Mineral Inventory, online database, October 2022 update.

Schandl, E.S. and Gorton, M.P. 2007. The Scadding gold mine, east of the Sudbury Igneous Complex, Ontario: An IOCG-type deposit?; The Canadian Minerologist, v.45, p.1415-1441.

Schandl, E.S., Gorton, M.P. and Davis, D.W. 1994. Albitization at 1700±2 Ma in the Sudbury–Wanapitei Lake area, Ontario: Implications for deep-seated alkalic magmatism in the Southern Province; Canadian Journal of Earth Science, v.31, p.397-607.

HIGHLIGHTS

- **Graphite is listed as a Critical Mineral in Ontario and globally**
- **More than 120 graphite occurrences are documented in southern Ontario**
- **Southern Ontario has excellent local, national and international transportation infrastructure**

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Graphite – Grey Gold!

Graphite has been in use from at least the fourth millennium BCE as ceramic paint additive for pottery (https://encyklopedie.ckrumlov.cz/en/mesto_histor_dolova/), refractory material in molds, and in carbonizing steel, arc furnace electrodes, lubricants, brake linings, portable electronics (MacKinnon and LeBaron 1992) and yes, pencils! Today graphite is an essential component of batteries for electric vehicles and other technologies. Graphite is listed as a Critical Mineral in Ontario and globally.

In April 2020, Allied Market Research released a report stating the global graphite market, worth US$13.3 billion in 2019, is projected to increase to US$21.6 billion by 2027, with an anticipated compound annual growth rate (CAGR) of 5.3% from 2020 to 2027. This growth in the graphite market is driven by an increase in demand for lithium-ion batteries around the world as the use of electric vehicles continues to rise. Another driving factor in the increasing demand for graphite is the use of graphite electrodes in arc furnaces used in steel production (Graphite Market by Type | Opportunity Analysis and Industry Forecast, 2019–2027; www.alliedmarketresearch.com/graphite-market [accessed September 13, 2022]).

Southern Ontario Graphite Potential

Graphite has been mined in Ontario from at least the late 1800s to the 1990s. The Globe Mine (Figure 1), originally the International Mining Company of New York, is the first documented graphite-producing mine in Ontario (MacKinnon and LeBaron 1992). The mine operated from 1870 to 1875 then intermittently to 1915 under different names. The Globe Mining and Refining Company operated the mine from 1915 to 1919 (MacKinnon and LeBaron 1992). In 1889, graphite was also discovered along the shores of Whitefish Lake, Renfrew County. By 1896 the site had become the Black Donald Mine (www.eganvilleleader.ca/monthly-feature/black-donald-mines-buried-under-centennial-lake/), which continued operating until 1954, producing both flake and amorphous graphite. The Black Donald Mine (*see* Figure 1) was the most important producer of graphite in North America, producing 87 000 tonnes of graphite during its lifetime (LeBaron 2016). Three other mines operating during this period—Tonkin-Dupont (1911–1914), National Graphite (1915–1917), and Timmins (*see* Figure 1)—collectively produced 1000 tonnes of graphite (LeBaron 2016). From 1989 to 1994, the Kearny Graphite Mine produced 17 000 tonnes of flake graphite concentrate from around 1 million tonnes of ore (LeBaron 2016). During the 2015 field season, the OGS conducted a mapping and sampling program to better define the geology and mineral potential of the Centennial Lake area, just east of Matawatchan. The program resulted in the discovery of 5 new graphite occurrences approximately 13 km southwest of the

Mancini, L.M. 2023. Graphite – Grey Gold!; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2022–2023, p.63-68.

Black Donald Mine, in the Centennial Lake area. The graphite is associated with sulphide-rich gneisses and schists (Duguet, Duparc and Mayer 2015).

Graphite occurrences in the Central Metasedimentary Belt are found mainly in the Bancroft and Frontenac terranes (*see* Figure 1) as flake and/or amorphous deposits in highly metamorphosed (upper amphibolite to granulite facies) sedimentary rocks (Rogers et al. 1995). These metasedimentary rocks consist of calcitic and dolomitic marbles and siliceous paragneisses. The graphitic metasedimentary rocks occur either within or adjacent to transition zones between marble units and the paragneisses (LeBaron 2016).

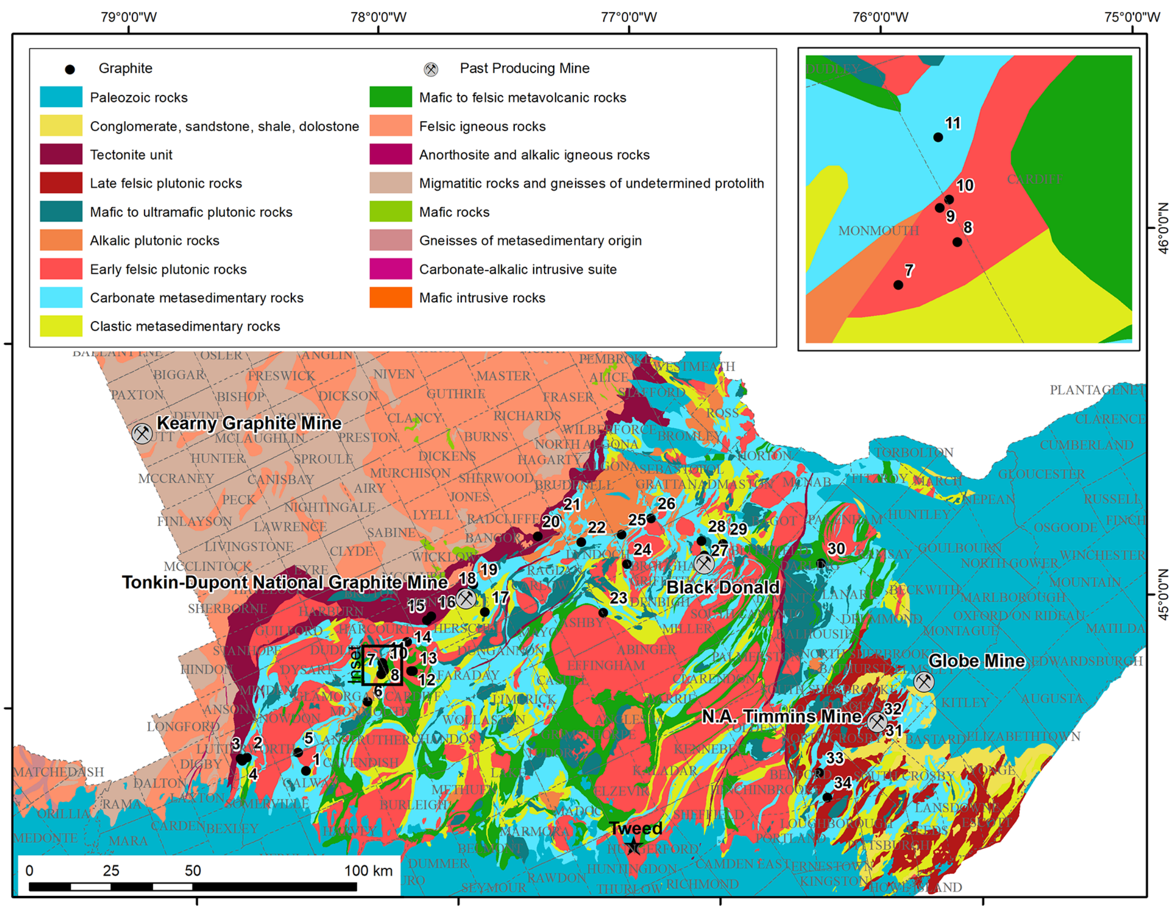

Figure 1. Simplified geological map of the Central Metasedimentary Belt of southern Ontario showing locations of graphite occurrences, prospects and past producers. Numbers on the map correspond to deposit names and the occurrence descriptions in Table 1 (data *from* the Ontario Mineral Inventory, Ontario Geological Survey 2022). Geology *from* Ontario Geological Survey (2011).

Further Reading

Several studies on the graphite potential of southern Ontario have been conducted over the years that examined graphite deposit types, environments and mineralogy. The studies, listed below, also have detailed descriptions of several deposits including past producers and prospects within the Central Metasedimentary Belt.

- *Graphite in Ontario*
  by D.F. Hewitt (1965)
- *Industrial Minerals of the Pembroke–Renfrew Area*
  by C.C. Storey and M.A. Vos (1981)

- *Graphite Development Potential in Eastern Ontario*
  by V.C. Papertzian and P.W. Kingston (1982)
- *Major Graphite Occurrences within the Frontenac Axis, Southeastern Ontario*
  by A. MacKinnon and P.S. LeBaron (1990)

Recommendations for Exploration

With the predicted increase in demand for graphite over the next few years, it is recommended to revisit graphite occurrences in southern Ontario. A search of the Ontario Mineral Inventory (OMI) online database revealed more than 120 documented graphite occurrences in the Central Metsedimentary Belt, 34 of which are listed in Table 1 and their locations indicated in Figure 1. Although the majority are currently on private or mining lands, the geological setting of the occurrences can be used as a model to explore new areas with similar geology.

Southern Ontario remains an excellent location for mineral exploration and development, and production, with its mineralogically diverse and complex geology. Excellent transportation infrastructure allows quick and efficient movement of products to local, national and international markets via roads, rail and Great Lakes shipping (Mancini 2022).

Table 1. Graphite occurrences in the Central Metasedimentary Belt of southern Ontario. Data *from* OMI (Ontario Mineral Inventory), Ontario Geological Survey 2022. Deposits in bold are available for claims registration. Numbers in the first column refer to occurrences in Figure 1.

No.	Deposit Name / Township	OMI File No.	Commodity Primary, Secondary	Mineralization Style	Rock Association(s)	Deposit Status	Land Status
1	Mount Irwin Galway	MDI31D15SE00016	gr Pb, Zn	[1]Disseminated flakes in marble	[1]Marble	Occurrence	Surface Rights Owned, Not open for claim registration
2	Miners Bay Lutterworth	MDI31D15SW00018	gr mb, msp	[2]Disseminated flakes in marble	[2]Marble	Occurrence	Surface Rights Owned, Not open for claim registration
3	Cedar Lake Lutterworth	MDI31D15SW00022	gr	[2]Disseminated flakes in marble	[2]Marble	Occurrence	Surface Rights Owned, Not open for claim registration
4	Otter Lake Lutterworth	MDI31D15SW00016	gr mb, py, po	[2]Disseminated flakes in marble	[2]Marble	Occurrence	Surface Rights Owned, Not open for claim registration
5	Birchbark Lake Snowdon	MDI31D15SE00036	gr	[1]Disseminated flakes in marble	[1]Marble	Occurrence	Surface Rights Owned, Not open for claim registration
6	Hot Spur Monmouth	MDI31D16NW00149	gr	[3]Disseminated flakes in marble	[3]Marble	Occurrence	Surface Rights Owned, Not open for claim registration
7	Concession XIII, Lot 32 Monmouth	MDI31E01SE00014	gr	[3]Disseminated flakes in marble and pegmatite stringers	[3]Marble Pegmatite Syenite	Occurrence	Surface Rights Owned, Not open for claim registration
8	Concession XIV, Lot 35 South Half Monmouth	MDI31E01SE00013	gr	[3]Lenses of disseminated flakes in marble	[3]Marble	Occurrence	Surface Rights Owned, Not open for claim registration
9	Virginia Graphite Co. Monmouth	MDI31E01SE00135	gr	[3]Disseminated graphite in foliations in marble	[3]Marble	Developed Prospect Without Reported Reserves or Resources	Surface Rights Owned, Not open for claim registration

Table 1. *continued*

No.	Deposit Name / Township	OMI File No.	Commodity Primary, Secondary	Mineralization Style	Rock Association(s)	Deposit Status	Land Status
10	**Bick Cardiff**	**MDI31E01SE00042**	**gr aln**	**[4]Disseminated graphite in seams in marble**	**[4]Marble**	**Prospect**	**Available Known Restrictions on claim holder**
11	Tonkin-Dupont prospect Cardiff	MDI31E01SE00078	gr	[4]Disseminated flakes in marble	[4]Marble Syenite	Prospect	Surface Rights Owned, Not open for claim registration
12	**Cupcake Lake Cardiff**	**MDI31E01SE00066**	**gr**	**[4]Disseminated flakes in paragneiss**	**[4]Paragneiss**	**Occurrence**	**Available Known Restrictions on claim holder**
13	**Dickson and Riddell Cardiff**	**MDI31E01SE00227**	**Gr po, Mo**	**[4]Disseminated flakes in siliceous paragneiss**	**[4]Paragneiss Gneiss Syenite**	**Occurrence**	**Available Known Restrictions on claim holder**
14	B.E. MacDougall Cardiff	MDI31E01SE00041	gr phl	[4]Disseminated flakes in syenite pegmatite	[4]Pegmatite Marble Gneiss	Occurrence	Surface Rights Owned, Not open for claim registration
15	**Hound Lake Herschel**	**MDI31E01NE00012**	**gr**	**[5]Disseminated flakes in paragneiss and calcitic marble**	**[5]Paragneiss Marble**	**Prospect**	**Available No Known Restrictions on claim holder**
16	F. Peever property Herschel	MDI31E01NE00013	gr	[4]Disseminated flakes in rusty gneiss	[4]Gneiss Pegmatite	Occurrence	Surface Rights Owned, Not open for claim registration
17	G. Rutledge property Monteagle	MDI31F04NW00015	gr	[4]Disseminated flakes in marble intruded by granite gneiss and pegmatite	[4]Marble Granite Pegmatite	Occurrence	Surface Rights Owned, Not open for claim registration
18	National Graphite (1915–1917) Tonkin-Dupont (1911–1914) Monteagle	MDI31F04NW00017	gr Mo, fel, msp	[4]Disseminated flakes in marble	[4]Marble Skarn Gneiss	Past Producer Without Reported Reserves or Resources	Surface Rights Owned, Not open for claim registration
19	Concession XIV, Lots 13 and 14 Monteagle	MDI31F04NW00016	gr	[6]Disseminated flakes in a rusty paragneiss underlain by marble	[6]Paragneiss Marble	Prospect	Surface Rights Owned, Not open for claim registration
20	**Diamond Lake Creek Radcliffe**	**MDI31F05SE00066**	**gr**	**[4]Disseminated flakes in paragneiss**	**[4]Paragneiss**	**Discretionary Occurrence**	**Available Known Restrictions on claim holder**
21	Reid Lake Brudenell	MDI31F06NW00014	gr	[4]Disseminated flakes in syenite	[4]Syenite	Occurrence	Surface Rights Owned, Not open for claim registration
22	Dupuis Creek Lyndoch	MDI31F06SW00011	gr phl, po	[4]Bands of disseminated flakes in marble and paragneiss	[4]Marble Paragneiss	Occurrence	Surface Rights Owned, Not open for claim registration
23	Allanhurst Mine Denbigh	MDI31F03SW00002	gr phl	[5]Disseminated flakes and graphite seams in micaceous marble and disseminated flakes in pegmatite	[5]Marble Pegmatite Syenite	Developed Prospect Without Reported Reserves or Resources	Surface Rights Owned, Not open for claim registration

Table 1. *continued*

No.	Deposit Name / Township	OMI File No.	Commodity Primary, Secondary	Mineralization Style	Rock Association(s)	Deposit Status	Land Status
24	Beidelman and Lyall Lyndoch	MDI31F06SE00005	gr phl	[4]Bands of disseminated flakes in marble and paragneiss	[4]Marble Paragneiss	Developed Prospect with Reported Reserves or Resources	Surface Rights Owned, Not open for claim registration
25	G.K. Pearse property Griffith	MDI31F06SE00025	gr	[7]Disseminated flakes in veins cutting marble	[7]Marble Paragneiss	Discretionary Occurrence	Mining Claim
26	Extra Griffith	MDI31F06SE00002	gr phl	[8]Disseminated flakes and very fine graphite smears following layering in marble	[8]Marble Paragneiss	Occurrence	Surface Rights Owned, Not open for claim registration
27	Green Lake Brougham	MDI31F07SW00011	gr tr	[8]Evenly disseminated flakes in marble	[8]Marble	Discretionary Occurrence	Surface Rights Owned, Not open for claim registration
28	Coronation Resources Brougham	MDI31F07SW00040	gr py	[8]Disseminated flakes in marble and [9]gneiss	[8]Marble [9]Gneiss	Prospect	Mining Claim
29	**Boundary Scully Farm Blithfield**	**MDI31F07SW00036**	**gr**	**[4]Disseminated flakes in gneiss**	**[4]Gneiss Marble Pegmatite**	**Discretionary Occurrence**	**Available Known Restrictions on claim holder**
30	Indian River Darling	MDI31F01NW00002	gr	[4]Massive graphite in marble interbedded with paragneiss	[4]Marble Paragneiss Pegmatite	Prospect	Surface Rights Owned, Not open for claim registration
31	N.A. Timmins Mine Burgess	MDI31C09NW00013	gr Fe, Co, Zn, Ni	[10]Disseminated flakes in folded marble intercalated with paragneisses	[10]Marble Paragneiss Pegmatite	Past Producing Mine with Reported Reserves and Resources	Surface Rights Owned, Not open for claim registration
32	Burgess Graphite Burgess	MDI000000001198	gr	[10]Disseminated flakes in folded marble intercalated with paragneisses	[10]Marble Paragneiss Pegmatite	Prospect	Surface Rights Owned, Not open for claim registration
33	Meadow Lake Zone Bedford	MDI31C10SE00205	gr	[10]Disseminated flakes in folded marble intercalated with paragneisses	[10]Marble Paragneiss Granitic gneiss	Developed Prospect with Reported Reserves or Resources	Surface Rights Owned, Not open for claim registration
34	Bawden Mine Bedford	MDI31C10SE00024	gr	[10]Lenses, pods and disseminated flakes in marble intercalated with paragneisses	[10]Marble Paragneiss Granitic gneiss	Prospect	Surface Rights Owned, Not open for claim registration

Sources for mineralization style and rock association(s) descriptions: [1]Easton 1987; [2]Easton 1990; [3]Armstrong and Gittins 1968; [4]Martin 1983; [5]Hewitt 1965; [6]Hewitt 1954; [7]Themistocleous 1981; [8]Story and Vos 1981; [9]Hansen 1983; [10]MacKinnon and LeBaron 1990.

Abbreviations: aln, allanite; cp, chalcopyrite; fel, feldspar; gr, graphite; mb, marble; msp, mineral specimens; Mo, molybdenum; phl, phlogopite; po, pyrrhotite; py, pyrite; she, scheelite; tr, tremolite; tur, tourmaline.

References

Armstrong, H.S. and Gittins, J. 1968. Geology of Glamorgan and Monmouth townships, Haliburton County; Ontario Department of Mines, Open File Report 5021, 210p.

Duguet, M., Duparc, Q. and Mayer, C. 2015. Geology and mineral potential of the Centennial Lake area, northeastern Central Metasedimentary Belt, Grenville Province; *in* Summary of Field Work and Other Activities, 2015, Ontario Geological Survey, Open File Report 6313, p.19-1 to 19-16.

Easton, R.M. 1987. Geology of the Howland area, Haliburton, Peterborough and Victoria counties; Ontario Geological Survey, Open File Report 5639, 188p.

——— 1990. Geology of the Clyde Forks area, Frontenac, Lanark and Renfrew counties; Ontario Geological Survey, Preliminary Map P.3093, scale 1:50 000.

Hansen, J.E. 1983. Work report on the Black Donald Creek graphite prospect Brougham Township, eastern Ontario; by Geotest Corporation for Coronation Resources (Canada) Ltd., assessment file AFRI# 31F07SW9657, 97p.

Hewitt, D.F. 1954. Geology of Monteagle and Carlow townships; Ontario Department of Mines, Annual Report, 1954, v.63, pt.6, p.1-78.

——— 1965. Graphite in Ontario; Ontario Department of Mines, Industrial Mineral Report 20, 66p.

LeBaron, P.S. 2016. Flake graphite in the Grenville Province of southern Ontario; *in* Recommendations for Exploration 2016–2017, Ontario Geological Survey, p.72-76.

MacKinnon, A. and LeBaron, P.S. 1990. Major graphite occurrences within the Frontenac Axis, southeastern Ontario; Ontario Geological Survey, Open File Report 5729, 77p.

——— 1992. Graphite occurrences of the Frontenac Axis, eastern Ontario; Ontario Geological Survey, Mineral Deposit Circular 33, 31p.

Mancini, L.M. 2022. Critical mineral molybdenum in the Grenville rocks of southern Ontario; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2021–2022, p.4-9.

Martin, W. 1983. Industrial minerals of the Algonquin region; Ontario Geological Survey, Open File Report 5425, 316p.

Ontario Geological Survey 2011. 1:250 000 scale bedrock geology of Ontario; Ontario Geological Survey, Miscellaneous Release—Data 126–Revision 1.

——— 2022. Ontario Mineral Inventory; Ontario Geological Survey, Ontario Mineral Inventory (June 2022 update), online database.

Papertzian, V.C. and Kingston, P.W. 1982. Graphite development potential in eastern Ontario; Ontario Geological Survey, Open File Report 5377, 89p.

Rogers, M.C., Thurston, P.C., Fyon, J.A., Kelly, R.I. and Breaks, F.W. 1995. Descriptive mineral deposit models of metallic and industrial deposit types and related mineral potential assessment criteria; Ontario Geological Survey, Open File Report 5916, 241p.

Storey, C.C. and Vos, M.A. 1981. Industrial minerals of the Pembroke–Renfrew area, Part 2; Ontario Geological Survey, Mineral Deposit Circular 22, 214p.

Themistocleous, S.G. 1981. Geology of the Khartum area, Renfrew County; Ontario Geological Survey, Report 211, 55p.

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HIGHLIGHTS

- **Titanium and vanadium are essential to high-strength steel, and the use of vanadium flow batteries is expected to rise**
- **Grenville Province contains most of Canada's titanium- and vanadium-bearing iron deposits, hosted by anorthositic gabbro intrusions**
- **Analyze known iron occurrences and past-producing iron mine waste for a broader suite of elements**

Titanium and Vanadium in Southeastern Ontario – Untested Potential

In March 2022, the Ontario government released its Critical Minerals Strategy for 2022–2027 (www.ontario.ca/page/critical-minerals). Titanium and vanadium feature on Ontario's critical minerals list and are also classified as critical minerals by Canada (Natural Resources Canada 2021) and the United States (United States Geological Survey, news release, February 22, 2022).

Both metals are important components of high-strength steel alloys, with demand increasing as vehicle manufacturers and construction companies tend toward creating lighter weight, fuel-efficient vehicles and lowering costs by improving the strength-to-weight ratio of material used. Vanadium-titanium alloys have the best strength-to-weight ratio of any engineered material yet discovered, and their combination with aluminum produces a material strong and stable enough for jet engines and high-speed airframes. There are currently no acceptable substitutes for vanadium in aerospace titanium alloys (Kelley et al. 2017).

A widely growing use for vanadium is in vanadium redox flow batteries (VRB), as they show great potential for stabilizing energy distribution in renewable energy systems. Vanadium redox flow batteries store energy in a nonflammable, liquid electrolyte; the batteries do not degrade with cycling and can be scaled and located with great flexibility, making them ideal for long-duration green energy storage (Kelley et al. 2017).

Vanadiferous titanomagnetite deposits (VTM) are the principal global source of vanadium (Kelley et al. 2017). Vanadiferous titanomagnetite deposits are made of magmatic accumulations of magnetite and ilmenite, and are mined for iron, titanium and vanadium (FeTiV). They occur as laterally extensive layers and thick tabular bodies, or as complex intrusions and lenses in mafic to ultramafic intrusions and metamorphic rocks. The ilmenite and magnetite may be remobilized by metamorphism and hydrothermal fluids after intrusion of syenite and alkalic igneous rocks (Kelley et al. 2017).

FeTiV mineralization and potential deposits have been recognized across Ontario (Cundari and White 2015; LeBaron 2015; Puumala and Campbell 2019, 2020; Bousquet 2020; Péloquin 2021), but it is agreed that the Grenville Province (covering much of the Sudbury and Southern Ontario Resident Geologist Program (RGP) districts) holds most of Canada's titaniferous deposits (Rose 1969). E.R. Rose of the Geological Survey of Canada stated, "Large deposits of vanadium-bearing titaniferous magnetite are distributed in the Canadian Shield, particularly in the Grenville Province, associated with the gabbroic phase of anorthositic intrusions" (Rose 1973).

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Dorado-Troughton, M. 2023. Titanium and vanadium in southeastern Ontario – Untested potential; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2022–2023, p.69-73.

Of the many iron and iron-titanium occurrences in southeastern Ontario (Figure 1; Table 1), there are few with documented reports of vanadium, as iron occurrences historically may not have been analyzed for vanadium or titanium. The most significant are described below.

The Newboro deposit consists of 2 separate zones, known as the Matthews and Chaffey iron mines, which produced a total of about 20 000 tonnes of iron ore between 1858 and 1871. Total estimated reserves (non-NI-43-101-compliant) within the 2 deposits are 45 million tonnes averaging 26% Fe and 6.6% TiO_2 (Carter 1984). Samples of ore material from rock dumps were reported to contain 0.1% V_2O_5 (Robinson 1922). The Methuen Township deposit, formerly known as the Twin Lakes ilmenite deposit and currently owned by Trigan Resources Ltd., consists of a zone of massive ilmenite within the cumulate zone of an anorthositic gabbro body about 4 by 2 km in surface area. Exploration of the deposit in the 1980s defined reserves of 13.2 million tonnes averaging 21.7% TiO_2 to a depth of 165 m (Sangster et al. 1999). A sample of massive ilmenite collected by staff of the Tweed Resident Geologist Office in 2011 contained greater than 1000 ppm V_2O_5 (LeBaron 2015) and samples collected during an unpublished study of the Crow River Watershed returned greater than 2000 ppm V_2O_5 (Menard 1985). Other occurrences with anomalous vanadium content have been identified: the Pine Lake occurrence (up to 0.52% V_2O_5),

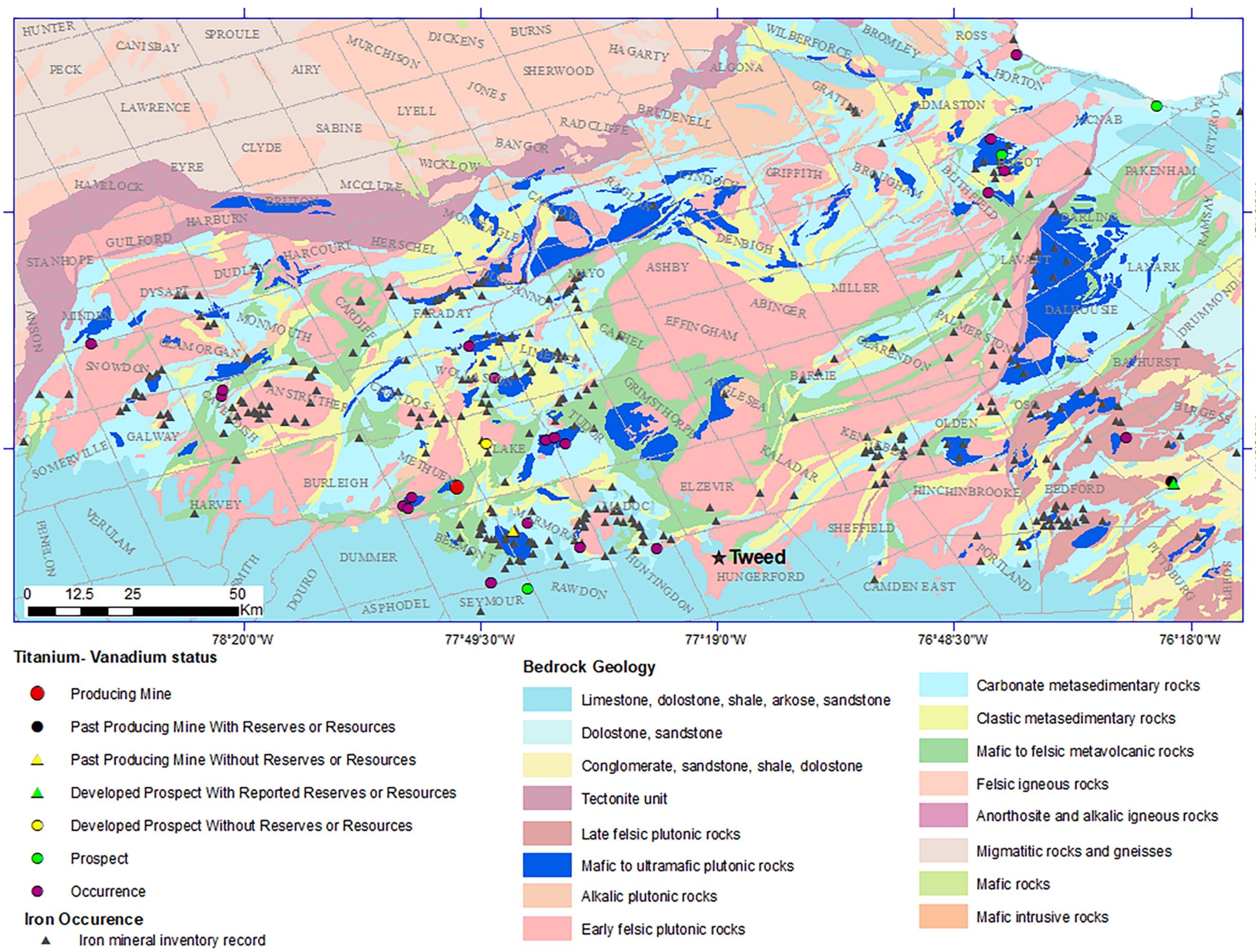

Figure 1. Map of southeastern Ontario, Southern Ontario Resident Geologist Program District, showing the location of documented titanium and vanadium occurrences and their association with iron occurrences and mafic intrusions (dark blue unit) (*see* Table 1; data *from* Ontario Mineral Inventory, Ontario Geological Survey 2022; geology *from* Ontario Geological Survey 2011).

a magnetite deposit within anorthositic gabbro; and the Orton occurrence (up to 0.34% V_2O_5), a magnetite zone at the margin of the Tudor Gabbro (Menard 1985; Wilson 1994). These grades compare favourably to the average grade of VTM deposits – between 0.2 to 1 weight % V_2O_5 (Kelley et al. 2017).

Although the majority of known FeTiV occurrences in southeastern Ontario (*see* Figure 1; Table 1) are on private land or have active claims currently, many land-holders are amenable to agreements and exploration should not be discounted. Companies that currently hold iron occurrences are encouraged to further test for the potential and extent of titanium and vanadium mineralization. The waste rock and tailings piles of past-producing iron deposits warrant further study, as well, as vanadium is proven to collect in iron slag and could be recovered as a valuable by-product (Menard 1985; Kelley et al. 2017; Millar 2021).

Furthermore, exploration for new titanium- and vanadium-bearing iron oxide deposits is recommended in southeastern Ontario, particularly in association with gabbroic and/or anorthositic intrusions (*see* dark blue unit in Figure 1). The Lavant gabbro suite is a good candidate, with a large and layered intrusion and known magnetite occurrences (LeBaron 2015). Many of the known magnetite deposits and untested iron-titanium occurrences near similar intrusions should be sampled and analyzed for titanium and vanadium.

Recommendations

- Examine gabbroic and anorthositic intrusions and related environments for magmatic FeTiV occurrences, and possible remobilized mineralization.
- Examine, sample and analyze (X-ray fluorescence (XRF) recommended) known iron occurrences to determine if vanadium and/or titanium are associated with them.
- Further examine, sample and analyze waste rocks and tailings piles of past-producing iron mines for potential to recover overlooked vanadium and or titanium.

Table 1. Highlights from iron-titanium, iron-vanadium and iron-titanium-vanadium occurrences in southeastern Ontario, Southern Ontario Resident Geologist District. Data *from* Ontario Geological Survey (2022). For a complete listing please see the OMI database or contact the author.

Property Name (township)	**OMI Number**	**Occurrence Status**	**Commodity (secondary)**	**Deposit Type**
Calabogie deposit (Bagot)	MDI31F07SE00009	Developed Prospect with Reserves or Resources	iron (vanadium)	magmatic metasomatic
Culhane Mine (Bagot)	MDI31F07SE00071	Prospect	iron (titanium, vanadium)	metasomatic
West Bluff Point (Bagot)	MDI31F07SE00119	Occurrence	iron (titanium)	magmatic metasomatic
Pershing (Belmont)	MDI31C05NW00029	Occurrence	magnetite (titanium, vanadium)	magmatic metasomatic
Pershing (Belmont)	MDI31C05NW00029	Occurrence	magnetite (titanium, vanadium)	magmatic metasomatic
Blithfield prospect (Blithfield)	MDI31F07SE00066	Occurrence	magnetite (titanium)	magmatic metasomatic
R.M. Easton samples (Cavendish)	MDI000000002463	Occurrence	iron (titanium, vanadium)	magmatic
Chenaux Gabbro (Horton)	MDI31F10SE00019	Occurrence	iron, titanium (vanadium)	magmatic
Tomahawk (Lake)	MDI31C12NW00002	Developed Prospect Without Reserves or Resources	iron (copper, talc, titanium, vanadium)	magmatic hydrothermal
Ricketts (Lake)	MDI31C12NE00109	Occurrence	iron (titanium)	magmatic

Table 1. *continued*

Property Name (township)	OMI Number	Occurrence Status	Commodity (secondary)	Deposit Type
Maloney (Marmora)	MDI31C12SW00002	Past Producing Mine Without Reserves or Resources	iron (nickel, copper, chromium, titanium)	magmatic metasomatic
Ridgeway (Marmora)	MDI31C12SW00122	Occurrence	iron (titanium, copper)	magmatic metasomatic
McNab Mine (McNab)	MDI31F08NW00004	Prospect	iron (hematite, titanium, vanadium)	hydrothermal
MRT Aggregates – Trigan Resources (Methuen)	MDI000000002331	Producing Mine	trap rock (titanium, iron, vanadium)	magmatic
Methuen Township Ilmenite (Methuen)	MDI31C12NW00114	Developed Prospect with Reserves or Resources	titanium (iron)	magmatic
Horse Lake (Methuen)	MDI31C12NW00127	Occurrence	iron, titanium	magmatic
Pioneer (Methuen)	MDI31C12NW00030	Occurrence	trap rock (titanium, iron)	magmatic
Matthews Mine – Newboro deposit (North Crosby)	MDI31C09NW00009	Developed Prospect with Reserves or Resources	magnetite, vanadium (titanium)	magmatic
W.H. Strong (North Crosby)	MDI31C09NW00071	Occurrence	magnetite (titanium)	magmatic
Allan Mills (Seymour)	MDI31C05NE00146	Prospect	magnetite (silver, vanadium)	metamorphic metasomatic
Chaffey – Newboro deposit (South Crosby)	MDI31C09NW00011	Developed Prospect with Reserves or Resources	magnetite (titanium)	magmatic
Orton (Tudor)	MDI31C12NE00122	Past Producing Mine Without Reserves or Resources	iron (titanium, vanadium)	magmatic
Hastings Road magnetite (Tudor)	MDI31C12NE00185	Occurrence	iron (titanium)	magmatic
Harper Lake (Tudor)	MDI31C12NE00188	Occurrence	magnetite, titanium	magmatic
Umfraville (Wollaston)	MDI31C13NW00057	Occurrence	magnetite, uranium (phosphate, titanium, cobalt)	magmatic

Abbreviations: OMI = Ontario Mineral Inventory.

References

Bousquet, P. 2020. Kamiskotia Gabbroic Complex: Looking at it under a different lens; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2019–2020, p.37-39.

Carter, T.R. 1984. Metallogeny of the Grenville Province, southeastern Ontario; Ontario Geological Survey, Open File Report 5515, 422p.

Cundari, R. and White G. 2015. Cu-Ni-PGE and Ti-V Potential in the Mesoproterozoic Badwater intrusive complex; Armstrong, Ontario; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2014–2015, p.9-10.

Kelley, K.D., Scott, C.T., Polyak, D.E. and Kimball, B.E. 2017. Vanadium; *in* Critical Mineral Resources of the United States–Economic and Environmental Geology and Prospects for Future Supply – Chapter U; United States Geological Survey Professional Paper 1802-U, 36p. https://doi.org/10.3133/pp1802U

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.

Menard, A.G. 1985. The geology of iron deposits in the Crowe River watershed; unpublished geological survey sponsored by Ministry of Natural Resources and the Crowe Valley Conservation Authority, Southern Ontario District Geologist's Office, 65p.

LeBaron, P. 2015. Titanium and vanadium in southeastern Ontario – Metals of the future; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2014–2015, p.35-37.

Natural Resources Canada 2021. Canada's critical minerals list, 2021; infographic, https://www.nrcan.gc.ca/sites/nrcan/files/mineralsmetals/pdf/Critical_Minerals_List_2021-EN.pdf

Ontario Geological Survey 2011. 1:250 000 scale bedrock geology of Ontario; Ontario Geological Survey, Miscellaneous Release—Data 126–Revision 1.

——— 2022. Ontario Mineral Inventory; Ontario Geological Survey, Ontario Mineral Inventory (October 2022 update), online database.

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.

Puumala, M.A. and Campbell, D.A. 2019. Fe-Ti-V and PGE-Cu-Ni potential in the Roaring River complex; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2018–2019, p.27-31.

——— 2020. Fe-Ti-V potential in the Roaring River complex near Allely Lake; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2019–2020, p.59-63.

Robinson, A.H.A. 1922. Titanium; Canada Department of Mines, Mines Branch Report, no.579, 127p.

Rose, E.R. 1969. Geology of titanium and titaniferous deposits of Canada; Geological Survey of Canada, Economic Geology Report, no.25, 177p.

——— 1973. Geology of vanadium and vanadiferous deposits of Canada; Geological Survey of Canada, Economic Geology Report, no.27, 130p.

Sangster, P.J., McGuinty, W.J., Papertzian, V.C., Steele, K.G., Lee, C.R., Laidlaw, D.A., Stewart, J.M. and Carter, T.R. 1999. Report of Activities, 1998, Resident Geologist Program, Southern Ontario Regional Resident Geologist Report; Ontario Geological Survey, Open File Report 5992, 76p.

Wilson, G.C. 1994. Mafic-ultramafic intrusions, base-metal sulphides, and platinum group element potential of the Grenville Province in southeastern Ontario; Ontario Geological Survey, Open File Report 5880, 196p.

Notes

Ontario Geological Survey
Regional and District Offices

▲ **Resident Geologist Office**	**Phone Number**
Kenora	807-456-1780
Kirkland Lake	705-718-8735
Red Lake	807-727-3272
Sault Ste. Marie	705-943-2219
Sudbury	249-885-1745
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Timmins	705-235-1615
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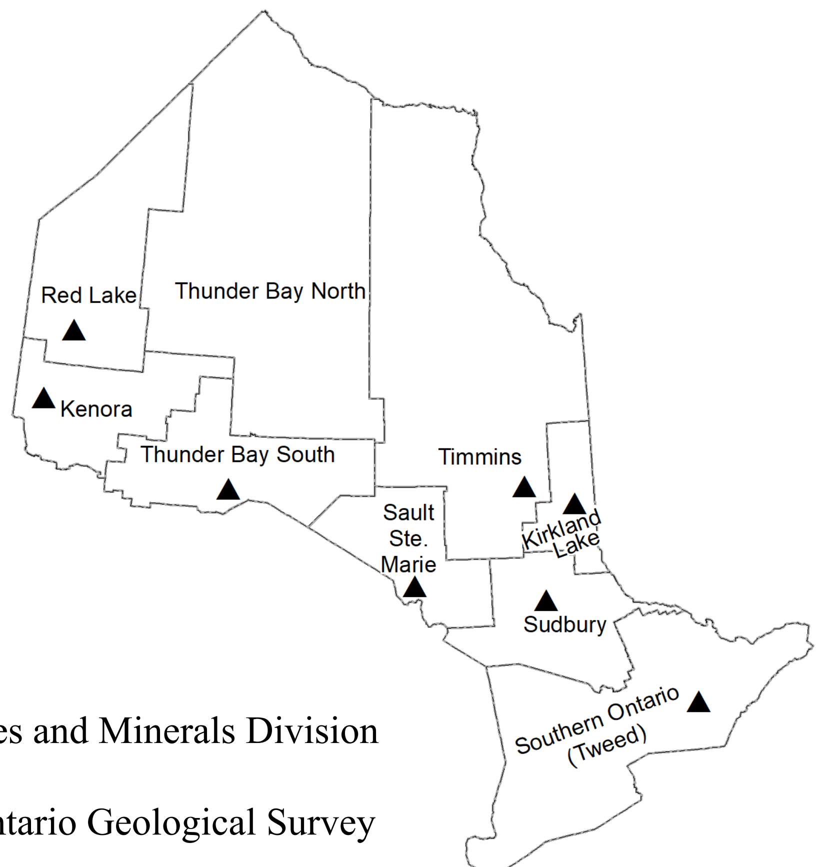
Toll Free (General)	888-415-9845



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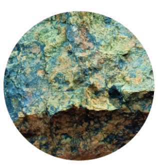
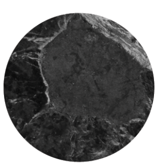

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