Recommendations for Exploration 2018–2019

Ministry of Energy, Northern Development and Mines
Ontario Geological Survey
Resident Geologist Program

Recommendations for Exploration

2018-2019

General Area that is Recommended for Mineral Exploration

ONTARIO CANADA

Photo courtesy of Karen Labonte

Ontario Geological Survey
Resident Geologist Program
Recommendations for Exploration 2018–2019

The Ontario Geological Survey is pleased to issue its 2019 Recommendations for Exploration. These recommendations are the product of the Ministry of Energy, Northern Development and Mines' dedicated and knowledgeable staff located across the province.

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

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

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

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About the Resident Geologist Program

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

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

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

Our services include

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

We provide geoscience information to support

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

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

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

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

Contents

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

Lewis, S., Paterson, W. and Rainsford, D.R.B. 2019. New geophysics-based targets in Sandy Lake and Favourable Lake areas; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2018-2019, p.9-14.

HIGHLIGHTS

- **Uranium bedrock samples correlate well with lake sediment geochemical anomaly**
- **Open ground with exposed massive sulphides, radioactive outcrop, trenching and diamond-drill hole locations**
- **Strongly peraluminous granites and pegmatites near muscovite-bearing intrusive rocks**
- **Open ground with exposed molybdenum, lithium, and copper samples near total rare earth element lake sediment anomaly**

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Revisit Exploration Potential with New Data in the Red Lake District

The geospatial interpolation method of inverse distance weighting (IDW) on select lake sediment geochemical data (Ontario Geological Survey 2001, 2002) from surveys conducted in the Red Lake Resident Geologist District, reveals several anomalous areas that denote the potential for new discoveries in the District. The opportunity for new discoveries of rare earth elements (REE) and base metals emerged through a review of the Mineral Deposit Inventory database (Ontario Geological Survey 2018), previous work by the Ontario Geological Survey (Figure 1) and a lack of exploration work in the area.

Aerobus Lake

The Aerobus Lake (NTS Zone 52K06NW) area is characterized by high values of uranium in lake sediment samples which coincide with anomalous values for Ni, Cr, Cu, Zn, V, Pb, Co, Rb, Li, Sc, Fe and Mn (Figures 2A and 2B). An exploration program conducted by Delta Uranium Inc. in 2008 identified 20 bedrock samples containing greater than 500 ppm U_3O_8 including 0.05% and 0.07% U_3O_8 over 1.7 m and 1.3 m, respectively, in drill holes (Metsaranta 2008).

The processing of a 100 m block-cell IDW algorithm for uranium in lake sediment samples (*from* Ontario Geological Survey 2001 and 2002) outlines 2 anomalous areas where little previous work has been conducted (Figure 2A). The area of bedrock samples with high uranium values collected by Delta Uranium Inc., correlate very well with lake sediment rare earth element (U, ±Pr, ±Dy, ±Sc) anomalies from the lake sediment geochemical survey conducted by the Ontario Geological Survey (Figure 2A). Additional work is warranted along the southern limb of the uranium IDW image where no bedrock sampling has been completed to date and on the northern portion of the lake sediment sample survey (Ontario Geological Survey 2001).

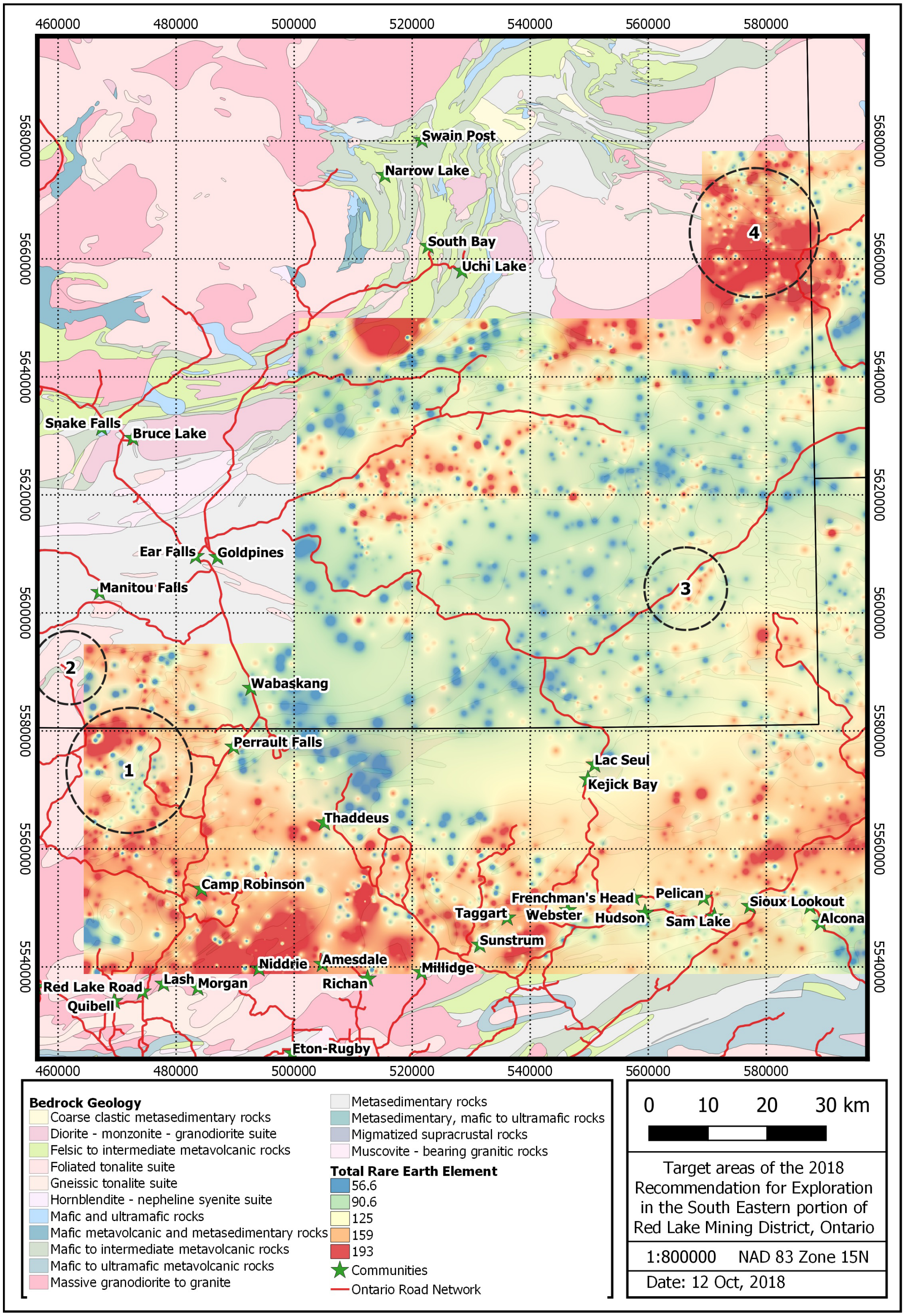

Figure 1. Interpolated spatial distribution (by IDW) of total rare earth element concentrations over bedrock geology (*modified from* Ontario Geological Survey 2011); lake sediment data *modified from* Ontario Geological Survey (2001, 2002); and overlain by the grid for the IDW algorithms, in the southeastern portion of the Red Lake District. Target areas are outlined in dashed circles.

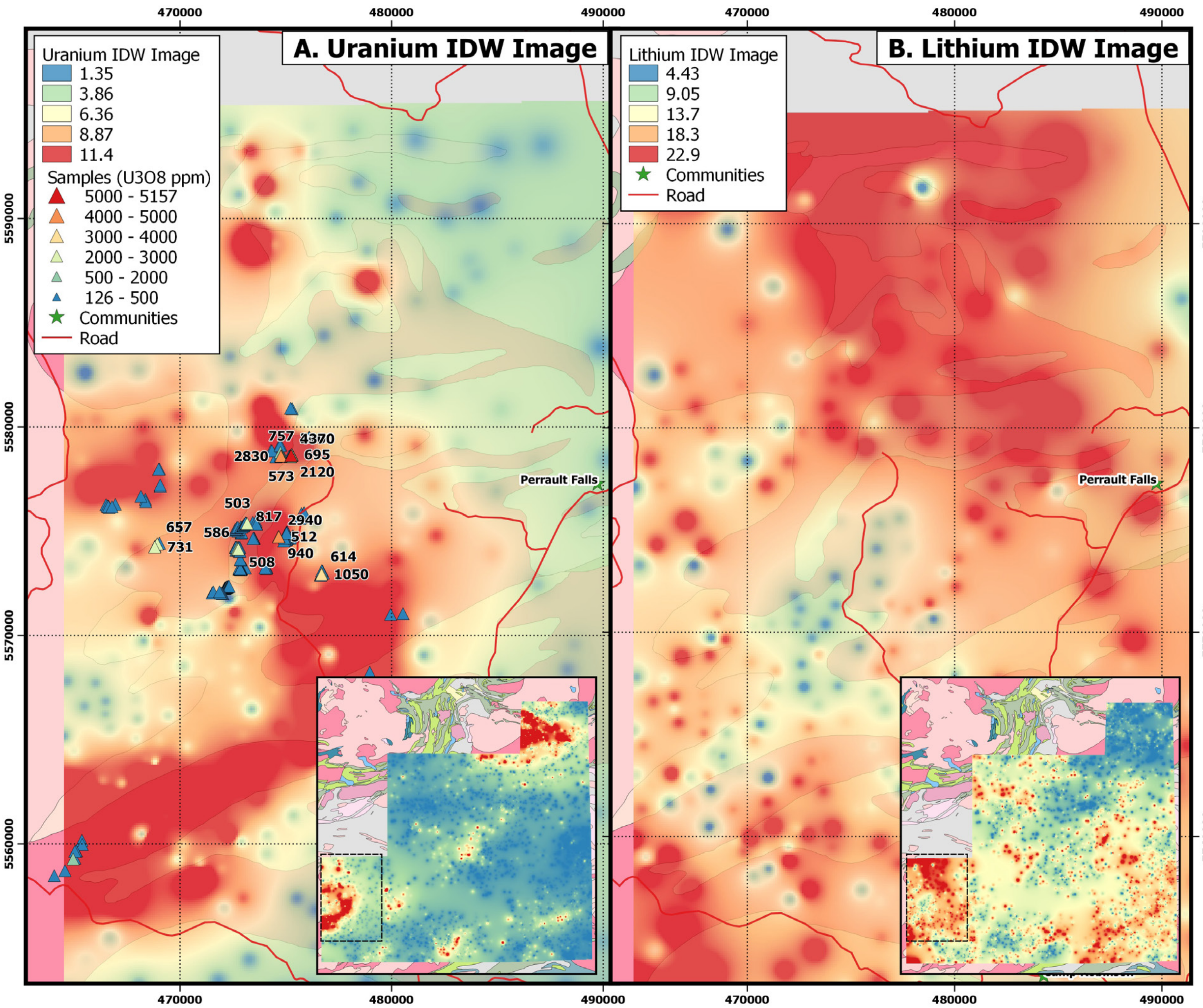

Figure 2. Area 1. Interpolated spatial distribution (by IDW) of elements in lake sediment, where **A**) shows uranium (ppm) and Delta Uranium bedrock samples (U_3O_8 in ppm); and **B**) shows lithium (ppm); lake sediment data *modified from* Ontario Geological Survey (2001, 2002); radiometric data *from* Metsaranta 2008; and overlain by the grid for the IDW algorithms. Insets show the entire lake sediment data set.

Burden Lake

In 1956 a small exploration program, conducted in the Burden Lake area (NTS Zone 52K05NE) identified several large sections (up to 25 feet) of massive pyrrhotite, pyrite and trace chalcopyrite in diamond-drill core (assessment file 52K05NE0002; Figure 3). A sketch map from this report illustrated several areas of exposed massive sulphides, radioactive outcrop, trenching and diamond-drill hole locations. Although some of the area covered by this assessment report now falls within the West English River Provincial Park, the bedrock geology (Ontario Geological Survey 2011) and slightly elevated residual magnetic intensities (Ontario Geological Survey 2017) show these areas to continue on a northeast strike into unencumbered ground. No assay results or specific scintillometer readings were provided in the assessment file. In 2011, Carmen Storey (then the Red Lake District Geologist) collected 2 pink granitoid intrusive rocks and 2 biotite-quartz-feldspar metasedimentary rocks at outcrops along the road access into this region (Lichtblau et al. 2013). Sample 2011CS010 showed enrichment in copper (524.9 ppm Cu), nickel (151.7 ppm Ni), chromium (283 ppm Cr), and to a lesser extent cobalt (60.6 ppm Cr) and zinc (88 ppm Zn). This sample was re-assayed using lead fire assay with gravimetric finish and determined both gold and silver were below detection. The presence of mafic to intermediate metavolcanic rocks, the abundant outcrop exposures in satellite view and the lack of available geochemistry data makes this a good base metal volcanogenic massive sulphide exploration target.

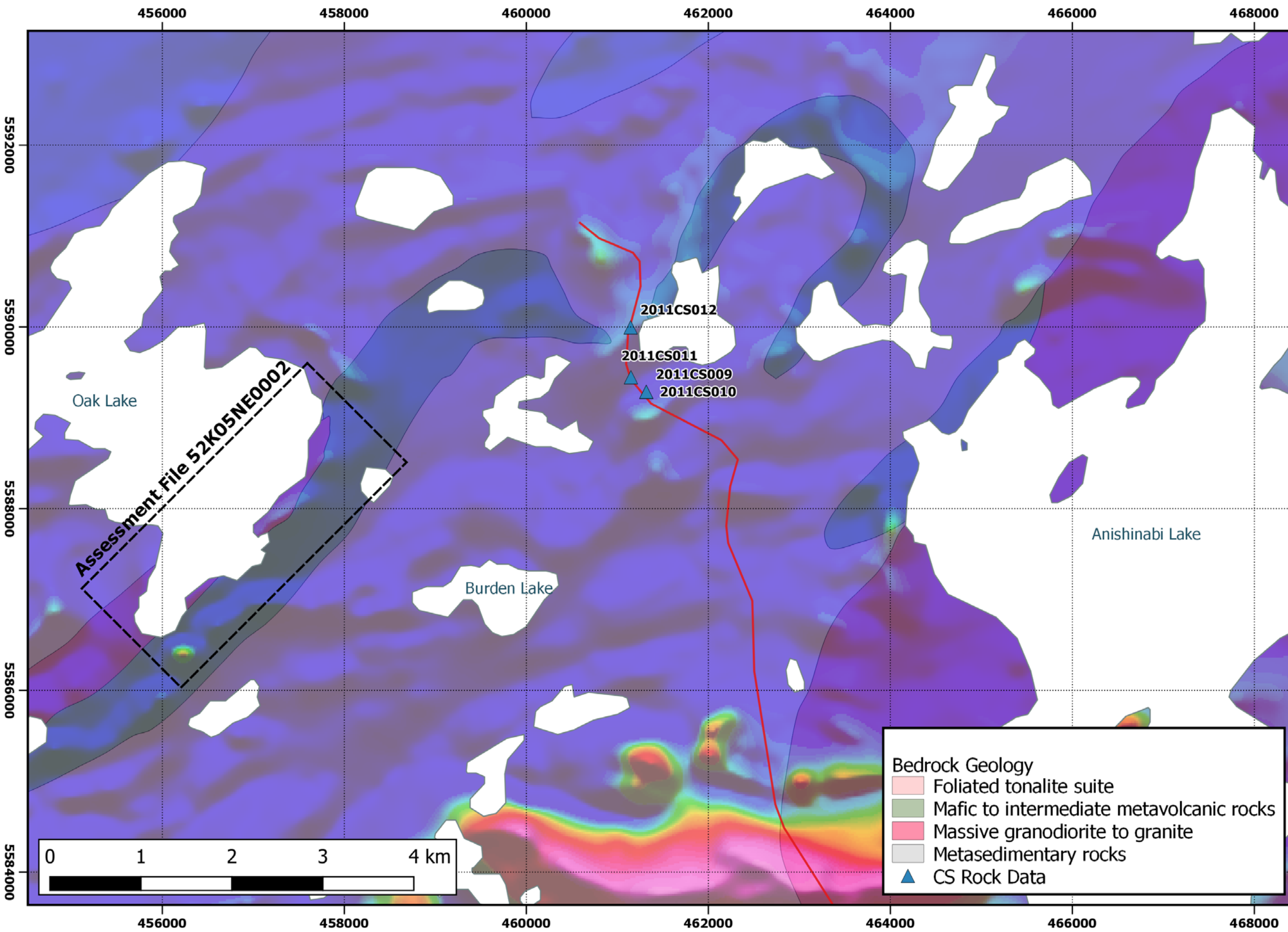

Figure 3. Area 2. Map of Burden Lake (NTS Zone 52K05NE) showing bedrock geology (*from* Ontario Geological Survey 2011) overlain by a semi-transparent image of the residual magnetic intensity (*from* Ontario Geological Survey 2017); showing the 2011 Red Lake Resident Geologist Staff rock sample locations (Lichtblau et al. 2013) (NAD83 UTM Zone 15N).

Antenna Lake

Antenna Lake is characterized by anomalous lake sediment concentrations for nickel, chromium, lithium, zinc, copper and cesium (Ontario Geological Survey 2001). No previous assessment work was filed regarding this location. On July 24th, 2018 the Resident Geologist staff from Red Lake conducted a field trip to the vicinity of Aerial Lake (NTS Zone 52K09SE; Figure 4) where they identified outcrop areas of tonalite, granodiorite, quartz-feldspar-biotite pegmatites and biotitic garnetiferous metasedimentary rocks (Figures 5A to 5D). Major element chemistry of the granitoid bodies was conducted to determine if any rare-metal or rare earth exploration potential existed. Rare-element–bearing (i.e., lithium, beryllium, tantalum) pegmatites are associated with peraluminous (where A/CNK>1) and strongly peraluminous granitoid rocks (characterized by A/CNK>1.2) (Table 1; Breaks, Selway and Tindle 2003). Although limited sampling was conducted in the Antenna Lake area, all 4 intrusive rock samples collected are strongly peraluminous. More work is recommended near Antenna Lake to identify the anomalous values for nickel, chromium, lithium, zinc and to confirm whether there are rare earth element-bearing pegmatitic phases in the muscovite-bearing granitic rocks to the northeast.

Table 1. Major element geochemical (XRF) results for rock samples collected at Antenna Lake. Major element data are in weight percent (wt %). The A/CNK was calculated by using molar ratios, as follows: (A/CNK = (wt % Al_2O_3 in sample/101.96128)/((wt % CaO in sample/56.08) + (wt % Na_2O in sample/61.979) + (wt % K_2O in sample/94.197)).

Sample	Al_2O_3	Bao	CaO	Cr_2O_3	Fe_2O_3	K_2O	MgO	MnO	Na_2O	P_2O_5	SiO_2	TiO_2	A/CNK
2018AL01	18.68	0.064	2.036	0.031	7.42	2.25	3.29	0.092	2.72	0.083	62.06	0.71	-
2018AL02	13.38	0.297	0.672	0.007	0.66	5.89	0.15	0.007	2.07	0.006	77.03	<0.01	1.22
2018AL03	20.03	0.108	2.324	0.011	3.26	5.04	1.65	0.019	4.08	0.09	62.51	0.37	1.22
2018SL05	20.02	0.081	2.228	0.01	2.6	3.99	1.28	0.017	3.95	0.051	66	0.29	1.35
2018SL06	21.22	0.052	3.572	0.004	1.26	1.15	0.7	0.015	4.78	0.044	67.59	0.16	1.36

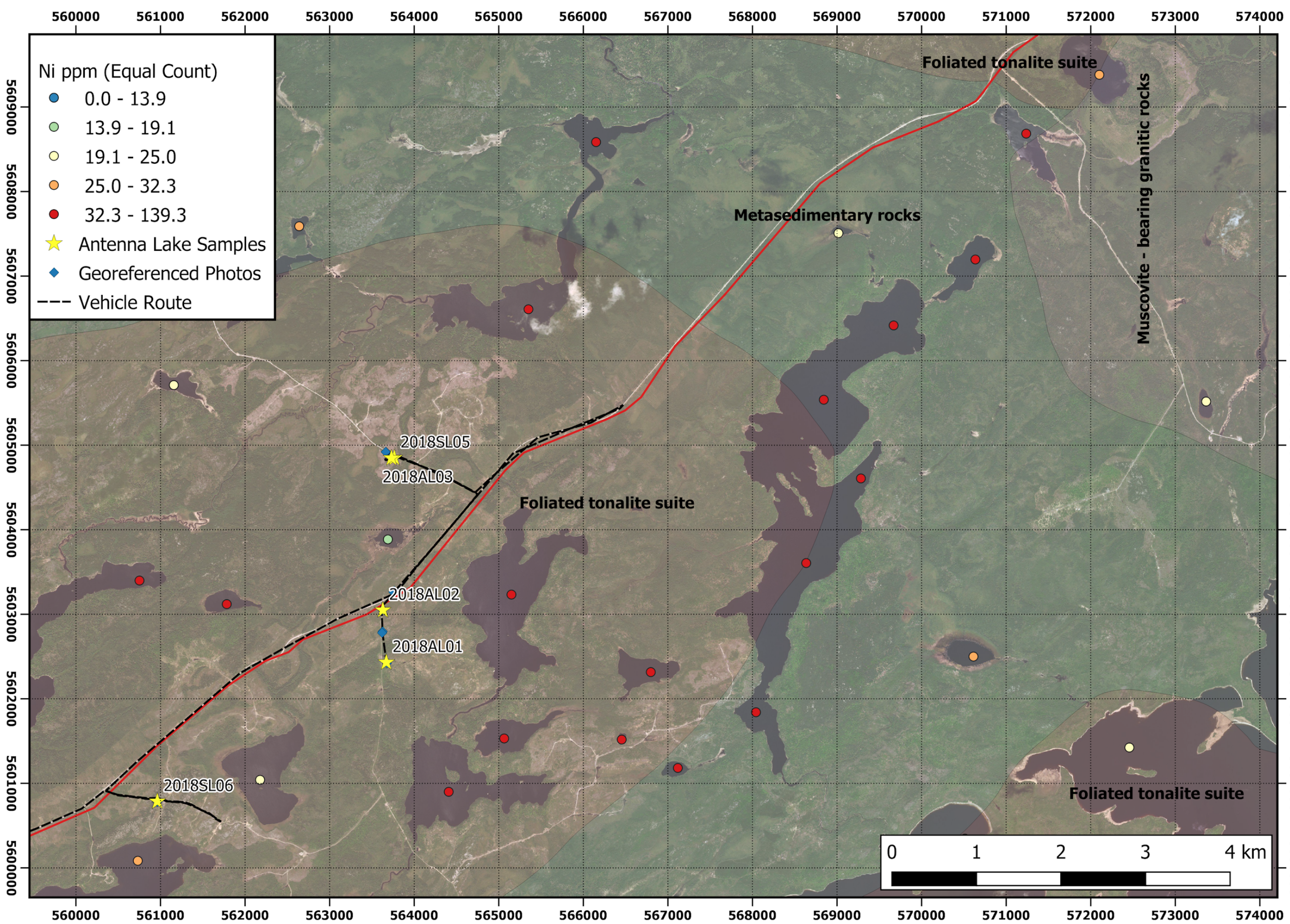

Figure 4. Area 3. Satellite image of the Antenna Lake area showing location of rock samples collected by the Red Lake Resident Geologist staff (yellow stars); location of lake sediment samples with nickel (*from* Ontario Geological Survey 2001; and the outline of the local bedrock geology (*modified from* Ontario Geological Survey 2011) (NAD83 UTM Zone 15N).

Figure 5. Area 3. Photos of rock samples from Antenna Lake. **A**) Sample 2018AL03: Biotite feldspar pegmatite sample from outcrop; **B**) Garnetiferous biotitic metasedimentary outcrop representative of sample 2018AL01; **C**) Sample S018SL06: Foliated tonalite–granodiorite, leucogranite sample; **D**) Centimetre-scale quartz biotite feldspar pegmatite phases hosted within a tonalitic granodiorite representative of sample 2018SL05.

Ferdinand Lake and Brokenmouth River

The Ferdinand Lake and Brokenmouth River areas (NTS 52O04NW and 52O04SW) host broad, multi-element (copper, molybdenum, uranium, total rare earth and platinum group elements, multi-site lake sediment anomalies (Figures 1, 2A and 6). There are 22 anomalous copper sites (39 to 86 ppm Cu), 10 anomalous molybdenum sites (4.04 to 11.32 ppm Mo), and 2 PGE sites (2.6 and 2.5 ppb Pd, 1.7 and 1.3 ppb Pt; Ontario Geological Survey 2002). In 1969, Madsen Red Lake gold mines (assessment file 52O04NW0005) conducted a limited trenching and short diamond-drill hole program. Notable assays reported from this zone include 0.36% Mo and 0.05 to 0.5% Li in grab samples (Sage and Breaks 1982); and 2.68% MoS_2, 0.1 to 1% Li grab samples, 0.96% MoS_2 over 0.64 m in diamond-drill hole No. 2. Sage and Breaks (1982) recognized that molybdenum is frequently associated with yellow-green muscovite and reported fairly continuous pyrite zones ranging from 3.8 to 10 cm on the north shore of Senior Lake. Fifteen kilometres southeast of Area 4, a highly evolved, complex-type spodumene-subtype pegmatite with internal zoning occurs (Breaks, Selway and Tindle 2003). In the 1957 Canadian Mines Handbook (Ontario Department of Mines 1957), Capital Lithium Mines Ltd. reported a non-NI 43-101 compliant resource of 2,297,000 tons grading 1.3% Li_20. The lack of reported lithium sampling and the semi-continuous pyrite zones suggest there is potential for more REE, base metal and precious metal discoveries in this area.

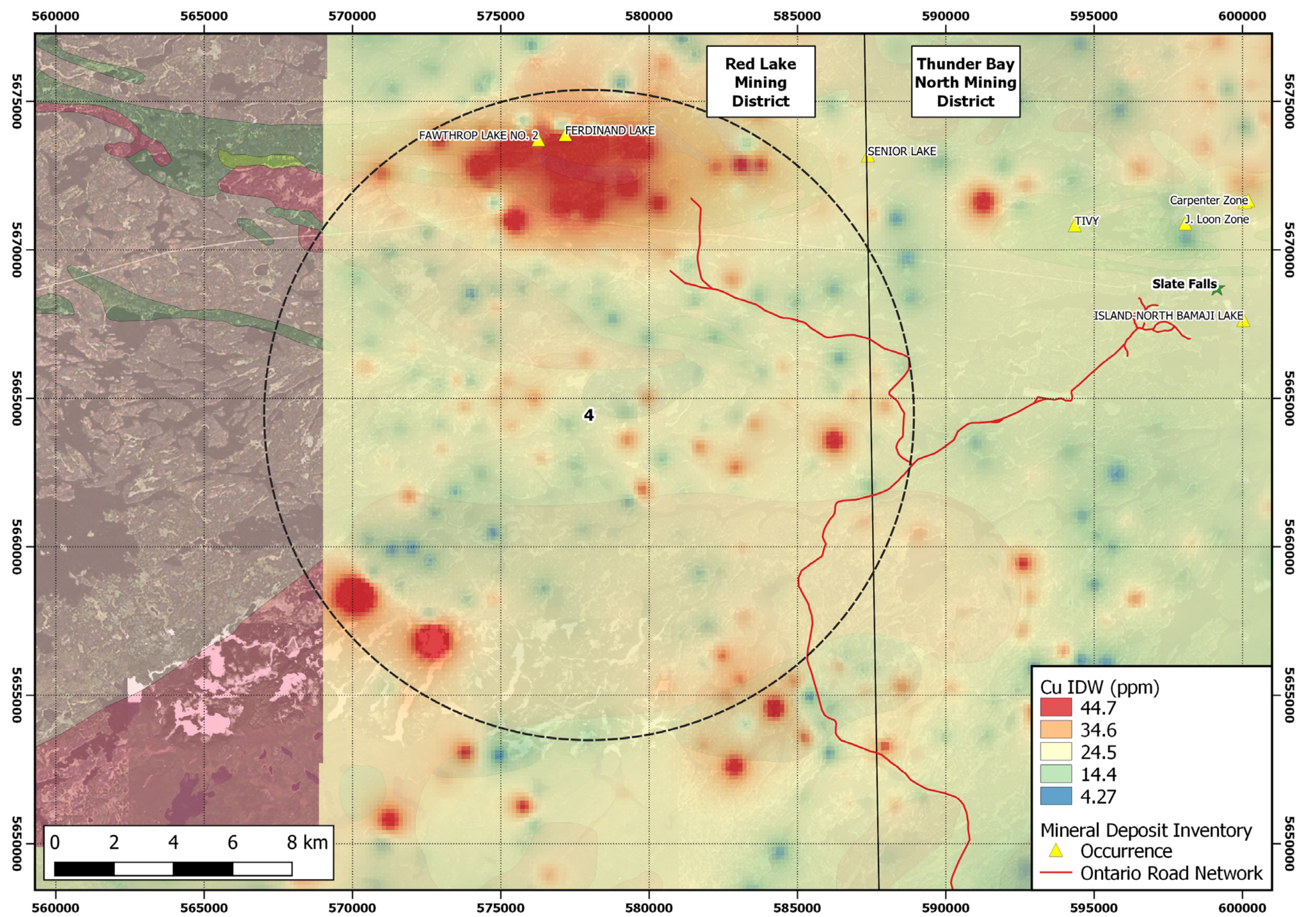

Figure 6. Area 4. Interpolated spatial distribution (by IDW) of copper (ppm) in lake sediment data (*modified from* Ontario Geological Survey 2001, 2002); overlain by bedrock geology (*modified from* Ontario Geological Survey 2011); and showing mineral occurrences (from Ontario Geological Survey 2018). Note the high copper lake sediment anomaly within northern part of Area 4 (NAD83 UTM Zone 15N).

The explorationist can redefine potentially anomalous bedrock occurrences of REE, base and precious metals in the Red Lake District by integrating the results of OGS lake sediment surveys, the recently completed OGS airborne geophysical survey and the assessment file and Mineral Deposit Inventory databases.

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HIGHLIGHTS

- **New airborne geophysical data set acquired over Sandy Lake and Favourable Lake areas of northwestern Ontario**
- **18 EM and high-resolution aeromagnetic targets presented for VMS, diamonds and precious metals**

New Geophysics-Based Targets in Sandy Lake and Favourable Lake Areas

The recently released helicopter-borne electromagnetic (EM) and magnetic survey (Geophysical Data Set GDS 1085 and maps M82919 to M82949; Ontario Geological Survey 2018a, 2018b) was flown in 2 blocks – one covering the Sandy Lake greenstone belt, the other block covering the Favourable Lake greenstone belt, for a total coverage of about 3000 km^2. The survey detected numerous EM anomalies and provided high-resolution images of magnetic features not visible in the province-wide aeromagnetic data acquired in the 1960s. As the most recent geological maps (M2178 and M2262; Bennet, Riley and Davis 1967 and Ayres et al. 1973, respectively) covering the whole area were published in 1967 and 1973, the understanding of the geology is not optimal, and the airborne geophysical results are intended to assist with future geological mapping projects.

Both areas are well endowed with mineral occurrences including the historic Berens River mine (157,341 oz gold; 5,676,486 oz silver; 5,105,873 lbs lead and 1,797,091 lbs zinc produced between 1938 and 1948; Lichtblau et al. 2006) and considerable exploration potential exists in these under-explored greenstone belts. There are 6 past recommendations for exploration within the Favourable Lake survey area indicating molybdenum, uranium, polymetallic, rare-earth and rare-metal pegmatites, and precious metals targets (Lichtblau 2011; Lichtblau 2018; Lichtblau and Puumala 2008; Lichtblau and Storey 2006; Lichtblau and Storey 2007; Storey 2011). A preliminary review of the airborne geophysical survey results has identified several targets that are of potential exploration interest. Precious metal, base metal VMS and kimberlite targets have been identified in the area using the geophysical data.

The targets were selected on the basis of shape, proximity to mineral occurrences, host rock and structure (known or inferred). Targets in staked areas (current to October 18, 2018) were excluded. The locations of the recommended targets for the Sandy Lake greenstone belt are shown in Figure 1 and those for the Favourable Lake greenstone belt are displayed in Figure 2. The target descriptions and centroid locations are summarized in Table 1.

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Table 1. Recommended geophysical targets. Target numbers and locations are shown on Figures 1 and 2. Geological compilation *from* Ontario Geological Survey 2011; MDI data *from* Ontario Geological Survey 2018c; target centroid co-ordinates are UTM Zone 15, NAD 83.

Target No.	Target Type	Centroid UTM E (NAD 83)	Centroid UTM N (NAD 83)	Comments
1	VMS	451005	5891457	Isolated magnetic anomaly with EM cluster. Similarities to McFaulds #1. Geological compilation (OGS 2011) indicates gneissic tonalite rocks, but there has been no recent mapping in the area.
4	Diamonds	525751	5899285	Small, circular magnetic anomalies - possible kimberlite responses. Consider also whether the responses could be due to isolated, disaggregated segments of iron formation.
5	Diamonds	525025	5897135	Small, circular magnetic anomalies - possible kimberlite responses. Consider also whether the responses could be due to isolated, disaggregated segments of iron formation.
6	VMS	452724	5885716	Clusters of weak to moderate EM anomalies with nearby magnetic feature - possible VMS target. Also consider whether feature could be a displaced greenstone sliver along inferred NW trending fault. Geological compilation (OGS 2011) indicates gneissic tonalite rocks, but there has been no recent mapping in the area.
7	Diamonds	525662	5896045	Small, circular magnetic anomalies - possible kimberlite responses. Responses could be due to isolated, disaggregated segments of iron formation.
8	Precious Metals	466336	5868359	Tight, S-shaped fold, shown by mag/EM horizons, in metasedimentary/metavolcanic unit (OGS 2011); may be associated with fracturing favourable for Au mineralization.
9	VMS	465129	5871770	Isolated 800 m long cluster of EM anomalies on edge of greenstone belt – potential VMS target.
10	Precious Metals & VMS	416001	5878611	Cluster of moderate to weak EM anomalies 1500 m (ESE) along strike from Au, Ag, Pb, Cu occurrence (Bennet, Riley and Davis 1967).
11	VMS	413530	5878917	Cluster of weak EM anomalies 1000 m (WNW) along strike from Au, Ag, Pb, Cu occurrence (Bennet, Riley and Davis 1967).
12	VMS	438019	5859937	Five line strong EM anomaly cluster under Favourable Lake, along strike from and approximately 4.6 km SE of Ag, Pb, Zn, Cu occurrence (Ayres et al. 1973). Closest outcrop, on north shore of lake, indicates the presence of felsic/intermediate metavolcanic rocks.
16	VMS	467486	5851785	Weak to moderate 3 line EM anomaly in felsic-intermediate metavolcanic rocks (OGS 2011) with multiple Cu, Au occurrences (OGS 2018c; Ayres et al. 1973) in vicinity.
17	Precious Metals & VMS	466011	5840943	Clusters of weak to strong EM anomalies. Geology indicated either as felsic-intermediate volcanic rocks (Ayres et al. 1973) or mafic/metasedimentary rocks (OGS 2011). Possible VMS target. Could also represent faulted continuation of Berens River Mine geology and possible Au target.
18	VMS	440765	5856911	Two clusters of moderate to weak EM anomalies in felsic-intermediate volcanic rocks (OGS 2011; Ayres et al. 1973).
19	Precious Metals	442410	5859034	Refolded fold (Ayres et al. 1973), possible continuation of Berens River Mine stratigraphy with multiple (formational) EM conductors and indications of faulting from magnetic pattern.

Target No.	Target Type	Centroid UTM E (NAD 83)	Centroid UTM N (NAD 83)	Comments
20	Precious Metals	454383	5855298	Cluster of EM anomalies associated with MDI Au occurrences (OGS 2018c); magnetic pattern suggests complex structure.
21	Precious Metals	460402	5854267	Strong EM and magnetic horizon apparently folded (closure to SE), associated with MDI Au occurrence (OGS 2018c). Orientation is parallel with Berens River mine veins. Area is partially staked.
22	Precious Metals	461674	5854865	Strong, 6 line EM anomaly with associated magnetic anomaly correlates with mapped iron formation (Ayres et al. 1973) and MDI Au occurrence (OGS 2018c).
23	VMS	462005	5851417	Moderate-strong EM anomalies with magnetic correlation in metasedimentary rocks (OGS 2011; Ayres et al. 1973), apparently folded (closure to SE) and faulted (local and regional NW-SE structures). Associated with MDI Cu occurrence (OGS 2018c).

Abbreviations: VMS = volcanogenic massive sulphides, MDI = Mineral Deposit Inventory, EM = Electromagnetic, E = metres easting, N = metres northing; OGS = Ontario Geological Survey

Note that EM targets were selected from picked anomalies appearing on the published maps and readers are advised to verify these features by viewing the EM profile data contained in the geophysical data set (Ontario Geological Survey 2018a, 2018b). It is suggested that users review past recommendations (Lichtblau 2011; Lichtblau 2018; Lichtblau and Puumala 2008; Lichtblau and Storey 2006; Lichtblau and Storey 2007; Storey 2011) in order to correlate geophysical recommendations with already suggested anomalous rare earth element, polymetallic and base-precious metal targets. Also, users are recommended to check the assessment files to determine if any of these targets have previously been investigated as well as to gain additional information that may help to follow up these features. As these recommendations are based on a preliminary review of the airborne survey results and not a thorough analysis of all the information, it is recommended that the data are evaluated in detail and in conjunction with a compilation of all available geoscience data in the area. In so doing, it is likely that many more exploration targets will be identified.

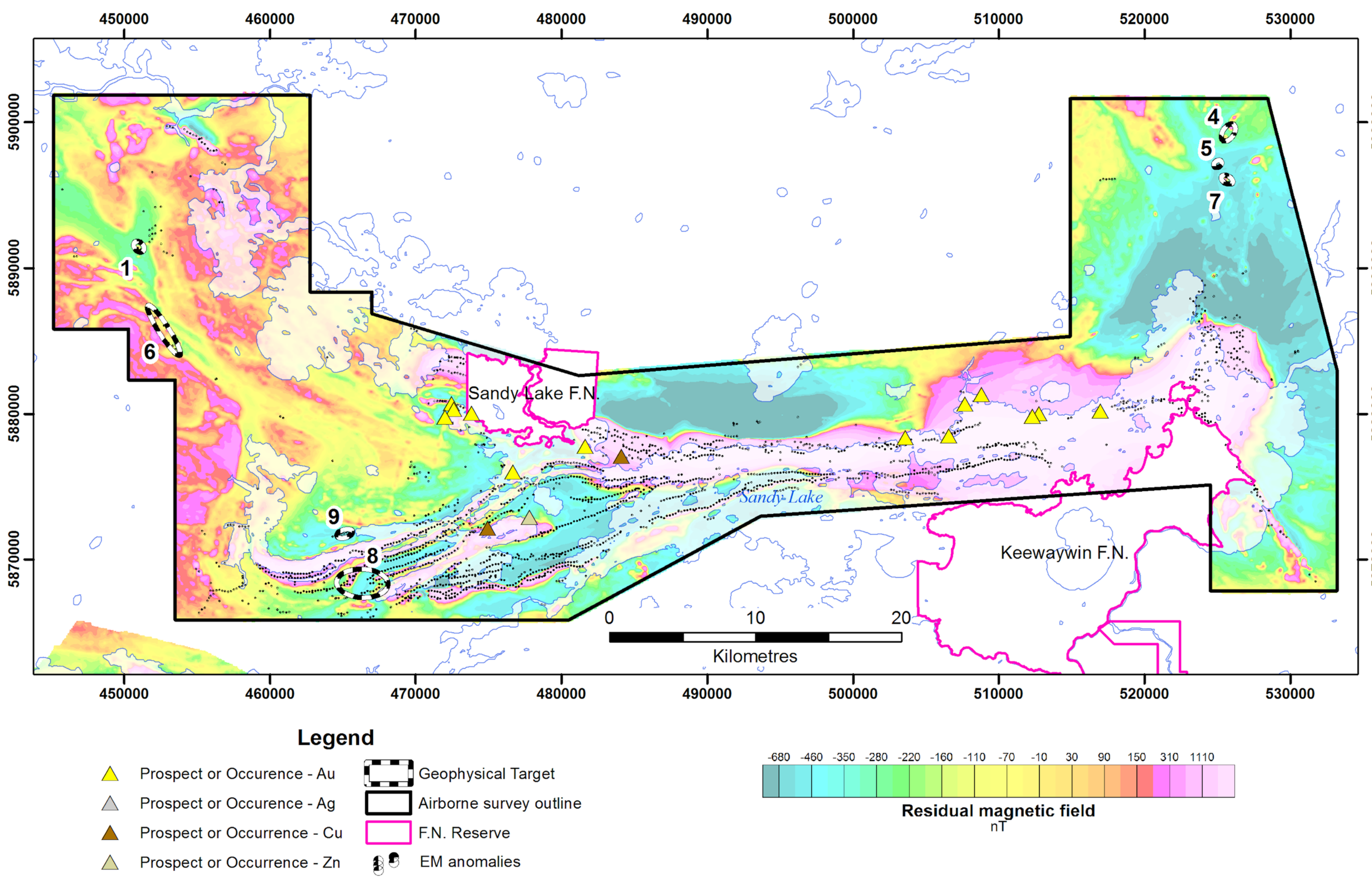

Figure 1. The residual magnetic field over the Sandy Lake block showing the survey outline, EM anomalies and recommended geophysical target areas, *modified from* Ontario Geological Survey 2018a and 2018b.

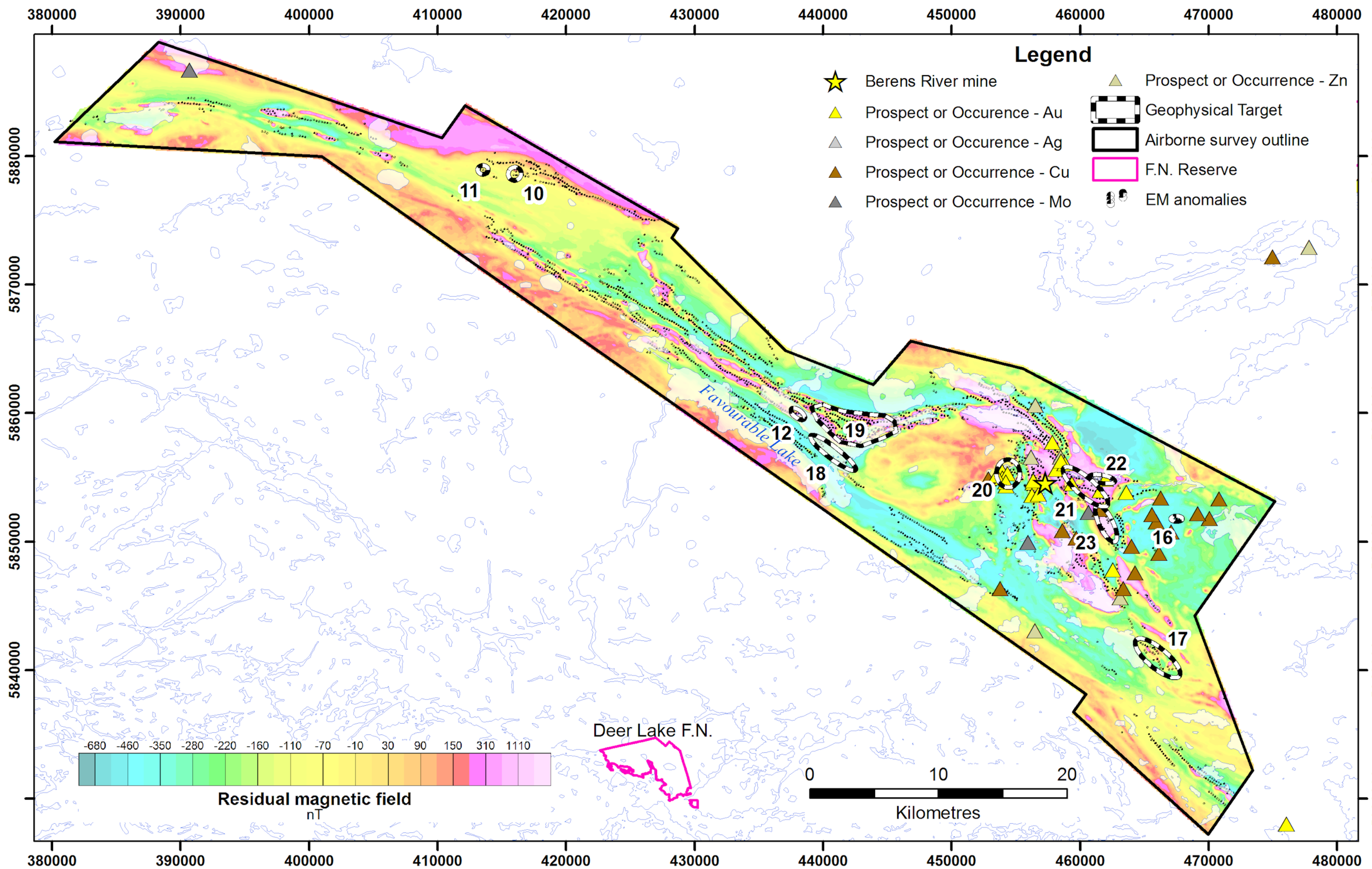

Figure 2. The residual magnetic field over the Favourable Lake block showing the survey outline, EM anomalies and recommended geophysical target areas, *modified from* Ontario Geological Survey 2018a and 2018b.

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HIGHLIGHTS

- **Pegmatites are known to host a number of economic commodities such as lithium, tantalum, rubidium, cesium and ceramic-grade feldspar and quartz**
- **Northwestern Ontario, particularly the Kenora District, contains numerous rare-element–bearing granite pegmatite located in a variety of rock types and geological settings**
- **Recognition of parental granites adjacent to subprovince and/or terrane boundaries can be critical in the examination of rare-element potential of an area**

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Rare-Element Pegmatite Potential: Superior Province and the Kenora District

The Superior Province contains more than 200 rare-element mineral occurrences that are hosted by the following rock types: metavolcanic (52%), clastic metasedimentary (23%), peraluminous granite plutons (20%) and tonalite-granodiorite plutons (5%) (Breaks, Selway and Tindle 2005).

Breaks, Selway and Tindle (2003) have proposed a link between peraluminous, S-type, fertile parent granites and rare-element pegmatites. Recognition of peraluminous granites is critical in the exploration for rare-element pegmatites. Rare-element–bearing (lithium, cesium, rubidium, beryllium, tantalum, niobium, gallium, thalium and germanium) pegmatites derived from a fertile, parental granite pluton are typically distributed over an area of 10 to 20 km^2 within 10 km of the fertile granite. Breaks, Selway and Tindle (2003) provide summaries of the geochemical, mineralogical and textural characteristics of rock types associated with rare-element pegmatites.

Breaks, Selway and Tindle (2005) grouped rare-element occurrences in the Superior Province based on rock type and pegmatite classification. The following is a summary of the geological setting of rare-element occurrences in the Superior Province.

- Peraluminous, S-type and pegmatite granites are typically situated along the boundaries of high-grade (amphibolite–granulite facies), metasedimentary rock-dominant subprovince boundaries.
- Fertile S-type granites are situated in medium-grade (greenschist–amphibolite facies) parts of the subprovince, such as the Dryden and Separation Rapids pegmatite fields (Figure 1) and are not located adjacent to high-grade metamorphic rocks.
- Rare-element pegmatites ± parental granites can be confined to major regional faults.
- Lithium-bearing rare-element pegmatites, such as the Raleigh Lake occurrences (*see* Figure 1), are located within greenstone belts and are not related to high-grade metamorphic rocks or major fault systems.
- Petalite-type pegmatites are found in the Separation Rapids area while spodumene-type pegmatites are commonly located in the rest of the Kenora Resident Geologist District.

The diversity of geological settings that are known to host rare-element–bearing pegmatite indicates that there is high-potential for additional mineralized zones in various areas of the Superior Province and especially in the Kenora District. A regional approach to identifying additional peraluminous felsic intrusions, fertile granites and mineralized pegmatite would include examining the geological settings associated with typical emplacement of rare-metal–enriched, granitic pegmatite systems.

Unexplored areas situated adjacent to known rare-element occurrences and along the extent of the Winnipeg River terrane boundary are prime locations to identify areas of peraluminous, S-type, fertile parent granites and rare-element–bearing pegmatite (*see* Figure 1). In many cases, the fertile granite is buried; the only surface expression associated with these intrusive rocks are the rare-element pegmatites themselves. Rare-element pegmatites are nonmagnetic and contain insufficient metallic minerals to be conductive. They typically do not contain radioactive minerals and may not have a sufficient specific gravity to allow them to be distinguished from the host rocks utilizing gravity surveys (Galeschuk and Vanstone 2005). Survey techniques typically used in metallic mineral exploration will not be useful in the search for fertile granites and pegmatites.

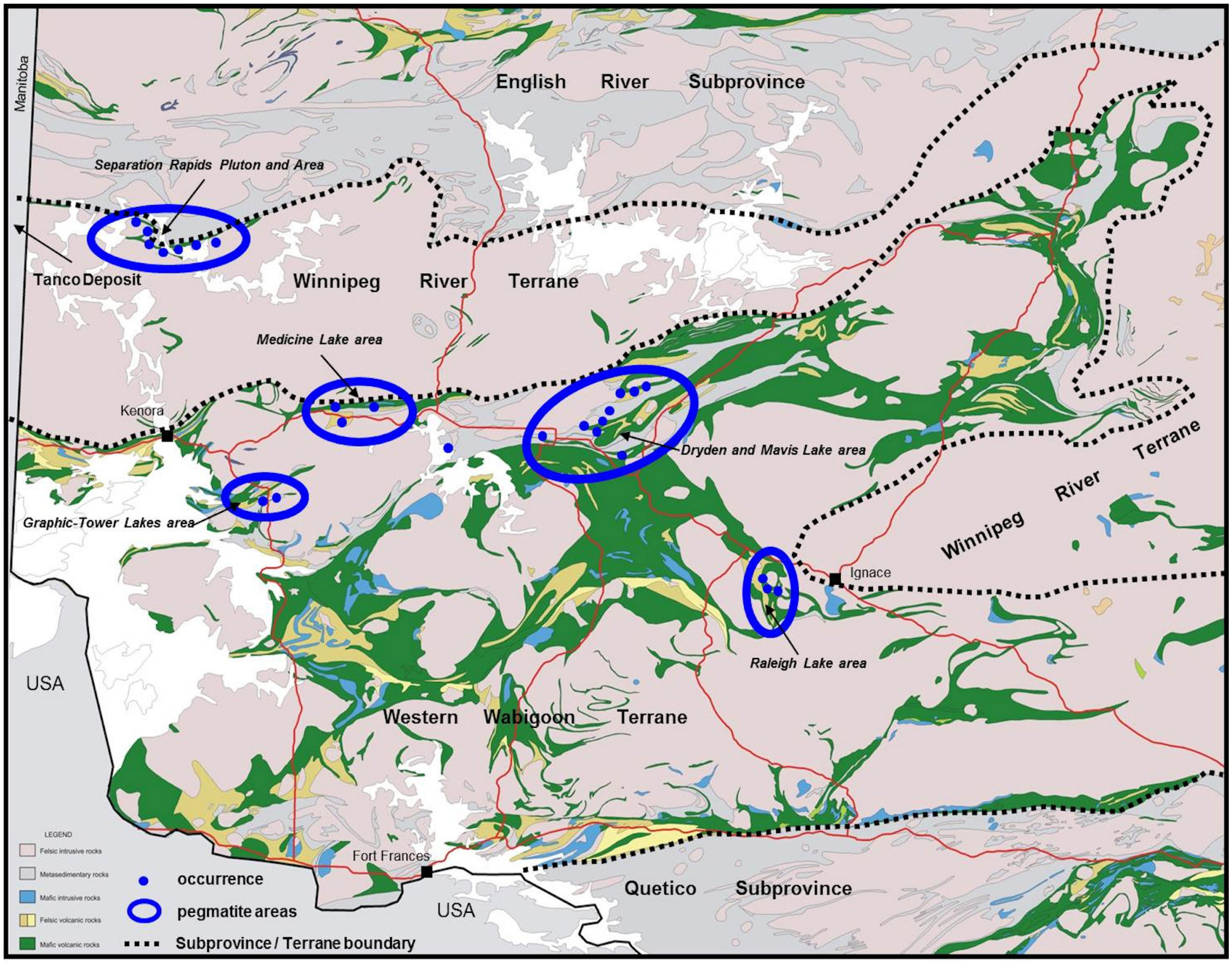

Figure 1. Bedrock geology, showing subprovince and terrane boundaries, pegmatite areas and location of rare-element occurrences in the Kenora Resident Geologist District (bedrock geology *modified from* Ontario Geological Survey (2011); terrane boundaries *modified from* Stott et al. (2010)). For other information, *see* Table 1.

Table 1. Known pegmatite fields and groups in the Kenora District (for locations, *see* Figure 1) and related references that summarize the rare-element potential of these areas.

Pegmatite Area	Reference(s)
Dryden Pegmatite Field	Breaks (1981, 1989)
Mavis Lake Pegmatite Group	Breaks (1993)
Gullwing–Tot Lakes Pegmatite Group	Breaks and Janes (1991); Breaks and Kuehner (1984); Breaks and Moore (1992); Breaks, Selway and Tindle (2001, 2003, 2005); Selway, Breaks and Tindle (2005)
Graphic–Tower Lakes Pegmatite	Breaks, Selway and Tindle (2001, 2003)
Medicine Lake Pegmatite	Breaks and Janes (1991); Breaks, Selway and Tindle (2001, 2003)
Separation Rapids Pegmatite Group	Breaks and Tindle (1996, 1997, 2001); Breaks, Selway and Tindle (2005); Breaks, Tindle and Smith (1999); Selway, Breaks and Tindle (2005); Tindle, Breaks and Webb (1998); Tindle and Breaks (1998, 2000)
Raleigh Lake Pegmatite	Breaks (1993)
Wabigoon–Winnipeg River Subprovince Boundary Area	Breaks, Selway and Tindle (2001, 2003, 2005); Selway, Breaks and Tindle (2005)
Regional Studies on Pegmatites	Breaks (1981, 1982, 1993, 2008)

The emplacement of pegmatite is accompanied by the alteration and development of a rare-element–enriched aureole within the adjacent host rocks. Galeschuk and Vanstone (2005) stated that "The best metals with respect to aureole thickness and intensity are Li, Cs, B, Sn, Be and Rb with the latter metal forming smaller, less intense aureoles". This mobility of metals associated with pegmatite emplacement can be a valuable asset when developing exploration programs. Selway, Breaks and Tindle (2005) and Galeschuk and Vanstone (2005 and 2007) provide summaries for the use of lithogeochemistry as a detection method to define buried pegmatite.

Geological mapping, structural studies, lithogeochemical sampling, testing B-horizon soil samples with the Enzyme Leach® analytical technique and biogeochemical surveys are some exploration techniques that have been applied to evaluate the rare-element potential of an area. Galeschuk and Vanstone (2005) provide summaries and comparisons of several of these exploration techniques that targeted buried rare-element–bearing pegmatite bodies near the Tanco lithium-cesium-rubidium-tantalum deposit in southeastern Manitoba.

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HIGHLIGHTS

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

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Metal Earth Program

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

In order to reveal the fundamental geological processes that were responsible for the formation of mineral deposits in Superior Province, 49 MSc, PhD students, research associates and field assistants will be conducting research for Metal Earth projects across northern Ontario and Quebec (Figure 1). Three of these transects are located in the Kenora District (Figure 2).

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

Thematic and data analytical research is planned to be completed within the area surrounding the 3 transects (*see* Figure 2). These types of activity were initiated in 2018 at the Stormy–Dryden Transect area. Frieman (2018) mentioned that "the supracrustal stratigraphy, intrusive history, structural evolution, and metamorphic development are largely under-investigated, and their relationships with economic resource distribution are unknown. This project aims to investigate and integrate these topics to propose a revised Precambrian and metallogenic evolution model of the Western Wabigoon".

Field work at the Stormy–Dryden transect focused mainly on regional lithological contact relationships, geochemical, and geochronological relationships between volcanic rock types. This field work involved regional lithological sampling, detailed geological mapping and initiation of 4 academic research studies ranging from BSc to PhD degrees. Similar field work is planned to be initiated in 2019 for the Sturgeon and Rainy transect areas (*see* Figure 2).

Field work and research analysis combined with seismic and magnetotelluric survey results will be used by Metal Earth to update the synthesis of the Western Wabigoon subprovince. This data will be used to develop a new geodynamic model for its formation which will be compared to other mineralized belts in the Superior Province. These concepts developed during and at the conclusion of the program could provide valuable information which can be used to determine areas to evaluate for mineral potential.

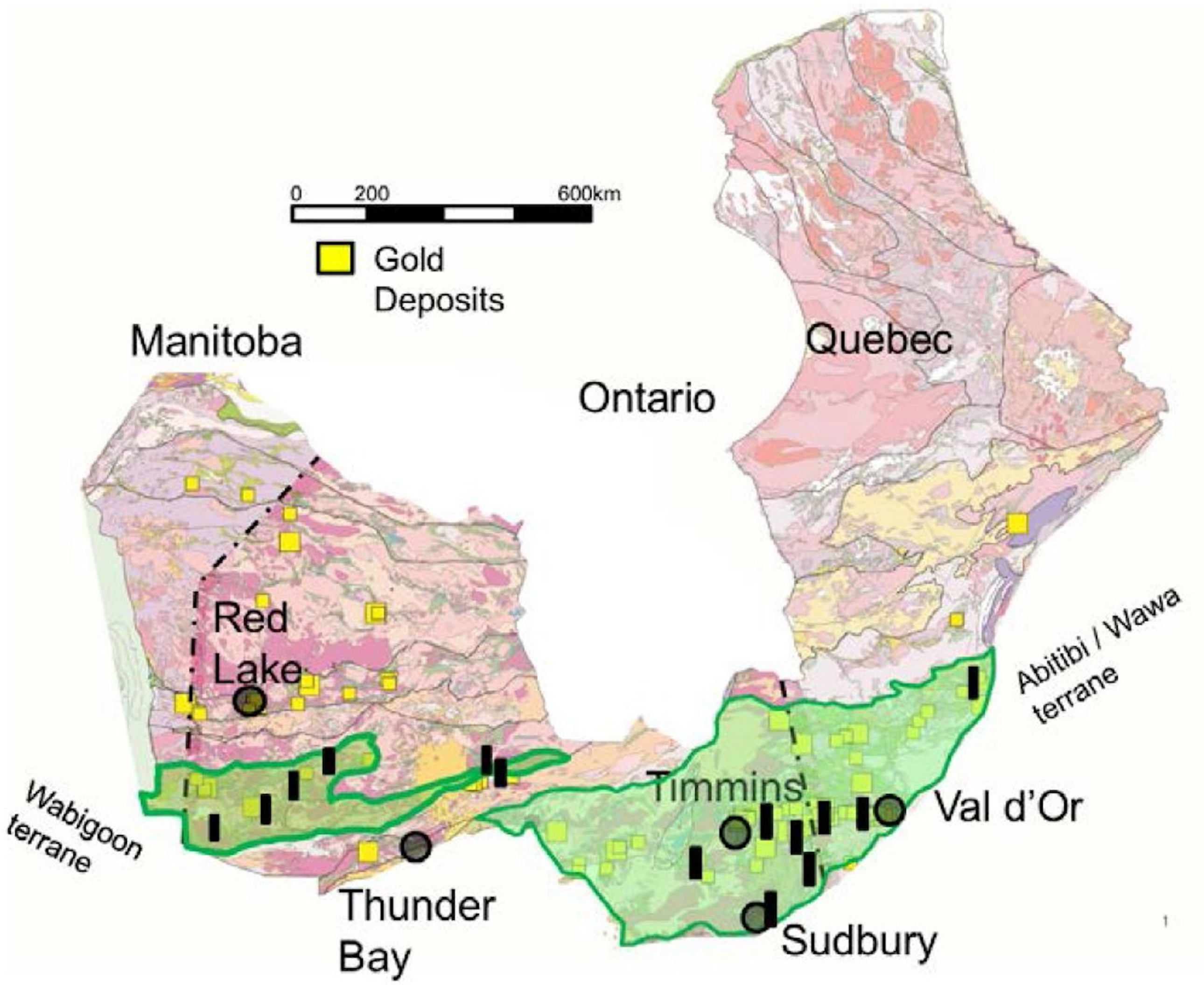

Figure 1. Geological compilation of the Superior Craton showing the Metal Earth transects (black bars), geological terranes (green shading) and selected communities (circles) (https://merc.laurentian.ca/sites/default/files/metal_earth_-_2018_annual_report_-_digital_distribution.pdf [accessed December 20, 2018]).

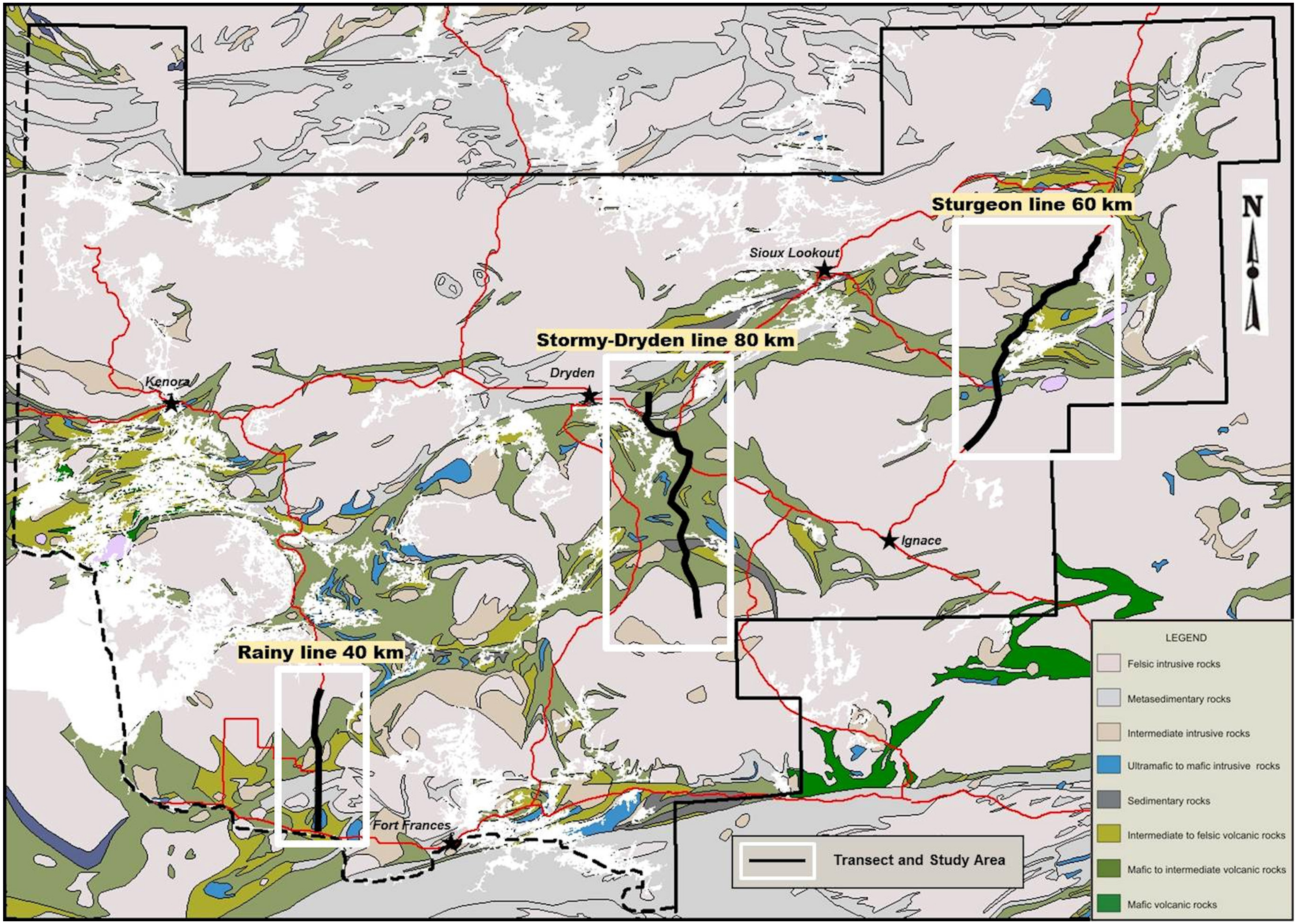

Figure 2. The 3 Wabigoon study transects (white boxes), located in the Kenora District, are outlined on bedrock geology (bedrock geology *from* Ontario Geological Survey 2011).

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HIGHLIGHTS

- **Fourbay Lake area has a cluster of strong gold anomalies in lake sediment located near northwest-trending lineaments that run subparallel to the gold-bearing northwest-trending corridor bounded by Beggs Lake and Fallen Lake faults**
- **The Fourbay Lake pluton is characterized as a magnetite-rich felsic intrusion favorable for exploration of gold deposits**

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Fourbay Lake Area Lake Sediment Gold Anomalies NE of Marathon

The Geological Survey of Canada (GSC) partnered with the Ontario Geological Survey (OGS) to complete lake sediment geochemical surveys covering the Marathon–Schreiber area in 1977, with the data having been re-analyzed in 1990 (Friske et al. 1991). Three anomalous sites in the Beggs Lake area returned some of the highest gold values of the entire survey (Scott et al. 2010) at 21, 18 and 13 ppb Au (*see* yellow dots, Figure 1). As noted below, recent exploration near these anomalies has resulted in the discovery of a number of new gold occurrences. Data from the same lake sediment survey defines additional areas that are anomalous in gold (*see* Friske, McCurdy and Day 1998). One such area that has seen little historic exploration activity is defined by a cluster of gold anomalies with 27, 11, 6, 5, 5, 4 ppb Au (*see* yellow dots in red circled area in Figure 1) within or near the Fourbay Lake pluton, 16 km northeast of Beggs Lake and 35 km northeast of Marathon.

In the Beggs Lake area, recent exploration by Canadian Orebodies Inc. has identified gold-bearing vein systems that are spatially associated with a northwest-trending structural corridor bounded by the Beggs Lake and Fallen Lake faults (Canadian Orebodies Inc., https://www.canadianorebodies.com/projects/hemlo-wire-lake/overview/ [accessed December 20, 2018]). In 2017, Canadian Orebodies discovered numerous new gold showings (red dots) within or near the Beggs Lake Stock and within the gold-bearing structural corridor that extends for more 15 km (*see* Figure 1). Canadian Orebodies reported a wide range of gold results from numerous showings and boulders in the Beggs Lake area ranging from 1 g/t up to 312 g/t gold (Figure 2).

Hattori (1987) proposed that oxidized felsic intrusions are spatially and temporally associated with Archean gold deposits within the Superior Province. These late mantle-derived plutons are magnetic, because of their high magnetite content. Beakhouse (2007) characterized the Fourbay Lake pluton as having a mineral assemblage indicative of oxidizing conditions. The airborne magnetic field data (Ontario Geological Survey 2002) also indicates that the Beggs Lake stock is highly magnetic.

The Fourbay Lake area is recommended for further exploration based on a similar geochemical and structural setting (i.e., northwest-striking faults) as the Beggs Lake area, along with the characterization of the Fourbay Lake pluton as a magnetite-rich felsic intrusion favourable for exploration of gold deposits. Areas near northwest-trending structures such as the Pinegrove Lake fault and several of the lake sediment anomalies on the western margin of the Fourbay Lake pluton were open for staking as of October 30, 2018 (*see* Figure 1).

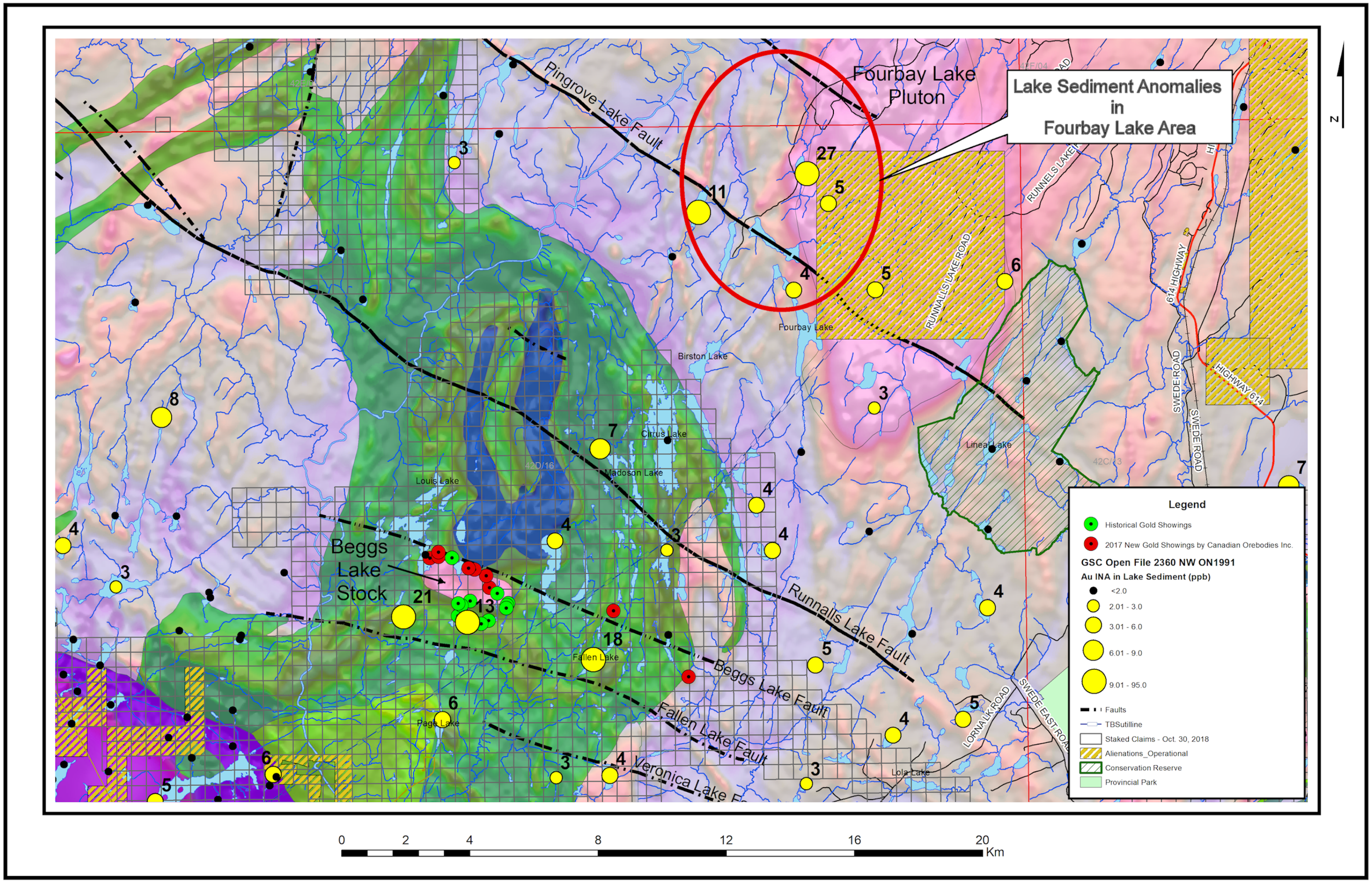

Figure 1. Regional geological map (*modified from* Ontario Geological Survey 2011) superimposed on the residual total magnetic field (*from* Ontario Geological Survey 1999, 2002) showing the location of the GSC lake sediment gold anomalies (yellow dots) (*from* Friske et al. 1991) and the location of staked claims (grey outlines) as of October 30, 2018. Note that the Fourbay Lake area anomalies located within the striped orange polygon are currently withdrawn from staking.

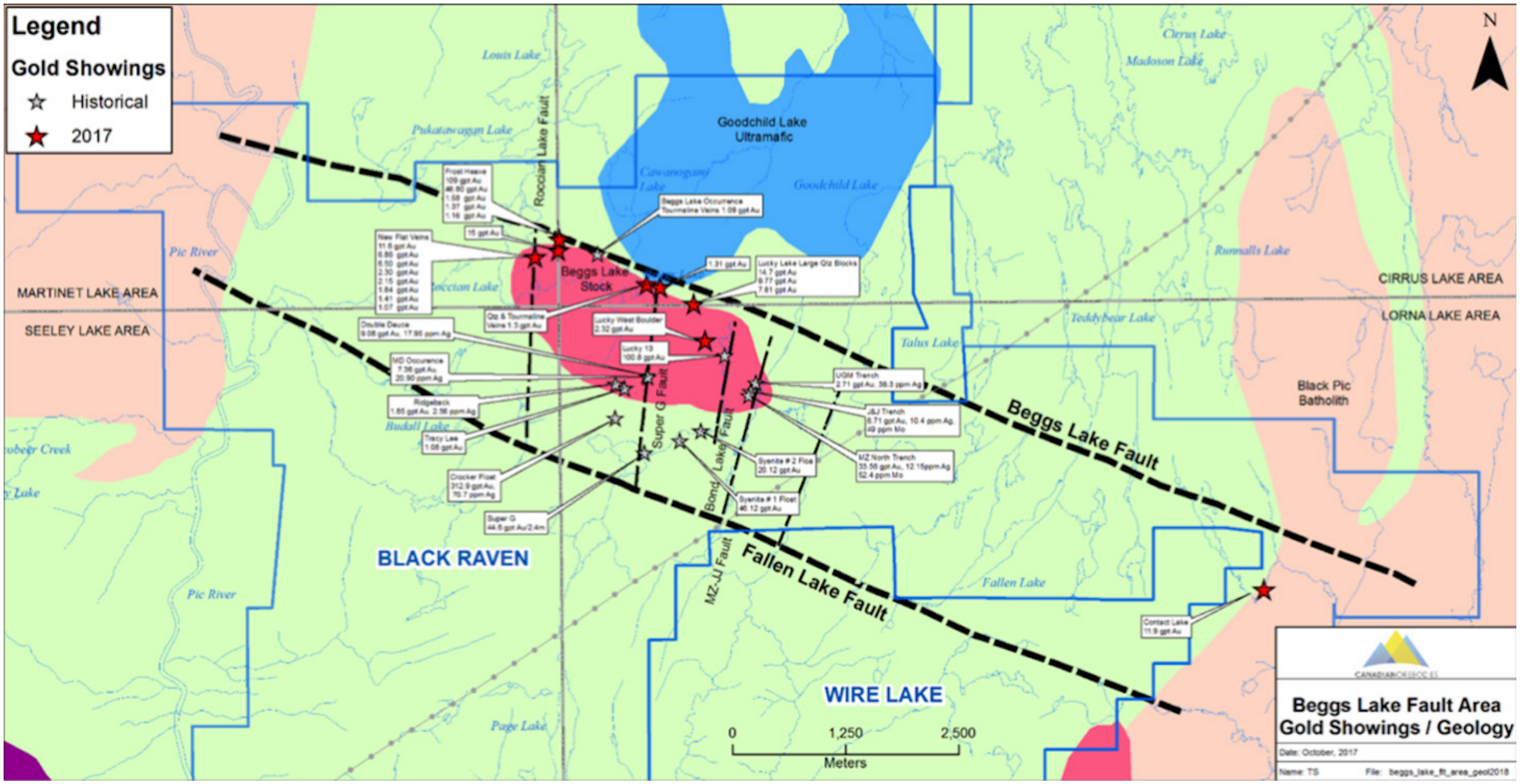

Figure 2. Regional geological map with results from historical gold showings (grey stars) and new gold showings (red stars) discovered by Canadian Orebodies Inc. in 2017 (from Canadian Orebodies Inc., https://www.canadianorebodies.com/projects/hemlo-wire-lake/overview/ [accessed December 20, 2018]).

The Runnalls Lake Fault (RLF) located 4 km northeast of Beggs Lake, is another favourable northwest-trending structure warranting further exploration. A notable lake sediment anomaly of 7 ppb Au is located just north of the fault, at Madoson Lake. Further east, this structure crosscuts an unnamed pluton that is magnetic along the margins (*see* Figure 1). Although, the lake sediment gold anomaly and RLF in the Madosan Lake area is currently staked by local prospector P. Moses, the property is available for option.

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HIGHLIGHTS

- **Lake sediment geochemistry and geophysical anomalies indicate potential for iron-titanium-vanadium (Fe-Ti-V) mineralization in the mafic to ultramafic rocks of the Roaring River Complex (RRC)**
- **Rocks of similar age and composition to those found in the Fe-Ti-V mineralized Empire Lake intrusion occur in an area with lake sediment Ti and V anomalies at the west end of the RRC near Allely Lake**
- **Known occurrences and lake sediment geochemical anomalies indicate platinum group element (PGE) exploration potential in mafic to ultramafic rocks located in the eastern portions of the RRC near the Highway 811 corridor**

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Fe-Ti-V and PGE-Cu-Ni Potential in the Roaring River Complex

The Roaring River Complex (RRC) is a 70 km long and 1 to 15 km wide intrusive rock complex (Figure 1) comprising several related intrusive phases that show a wide variability in compositions. The RRC has been classified as a sanukitoid suite intrusive complex that includes the following rock types: pyroxenite, gabbro, diorite, monzodiorite, monzonite and granodiorite (Stern, Hanson and Shirey 1989). Sanukitoid magmas are interpreted to have been derived from partial melting of mantle peridotite, making the mafic to ultramafic phases of these intrusive complexes attractive targets for copper-nickel-platinum group element (Cu-Ni-PGE) and iron-titanium-vanadium (Fe-Ti-V) exploration. The east-central portion of the RRC is already known to host a number of PGE (±Cu, ±Ni) occurrences near the Highway 811 corridor (McCrindle and Fingler 2001; Schnieders et al. 2002), while an occurrence of Fe-Ti-V mineralization occurs in the Empire Lake intrusion, an intrusive body that is thought to be related to the RRC and occurs near its western end (Flank 2014). The locations of these occurrences are shown on Figure 1.

The PGE occurrences within the RRC were discovered as a result of prospecting that was done to follow-up on the results of lake sediment geochemistry surveys that were published by the Ontario Geological Survey (OGS) in 2000 (Jackson and Dyer 2000; Ontario Geological Survey 2000). After completing a property visit in 2001, Schnieders et al. (2002) provided the following evaluation of the potential for further PGE discoveries in the mafic to ultramafic intrusive rocks that occur along Highway 811.

> The uniform, disseminated nature of the sulphide-PGE-mineralized zones and the number of such zones despite a paucity of outcrop suggest that additional zones are likely to be discovered in the course of further stripping or diamond drilling. Future exploration may also extend the 4 km length over which mineralized zones are currently known to be distributed and elucidate lithologic relationships and local structure. This will provide a context into which mineralization processes can be placed in order to plan additional exploration and generate new targets on this and neighbouring properties.

In spite of the recognized PGE potential of the RRC and the early exploration success, only a limited amount of exploration has been done in the area since the initial PGE discoveries (i.e., as noted by Bowdidge 2010), and most of the RRC is currently open for staking.

Iron oxide-hosted Fe-Ti-V mineralization has not historically been a focus of exploration in the RRC. However, with vanadium demand and prices expected to increase in the near future (https://investorintel.com/sectors/technology-metals/technology-metals-intel/vanadium-is-still-a-hot-sector-right-now-but-can-it-be-maintained/), and with the known occurrence of such mineralization in a related intrusion at Empire Lake, exploration for similar mineralization in the RRC is warranted.

Flank (2014) describes the Empire Lake Fe-Ti-V zone as follows.

> The work completed suggests a zone of Fe-Ti-V mineralization with a strike length of 1800m and width of 50-170m underlies the Empire Lake property. This horizon is defined by samples containing >0.1% V_2O_5 within a ferrogabbro with visible layers and/or veins of magnetite.

A number of information sources are available to help guide exploration in the RRC. A brief summary of some of this information is provided below. Further details can be obtained by contacting the Thunder Bay South Resident Geologist Program Office (*see* contact information provided below).

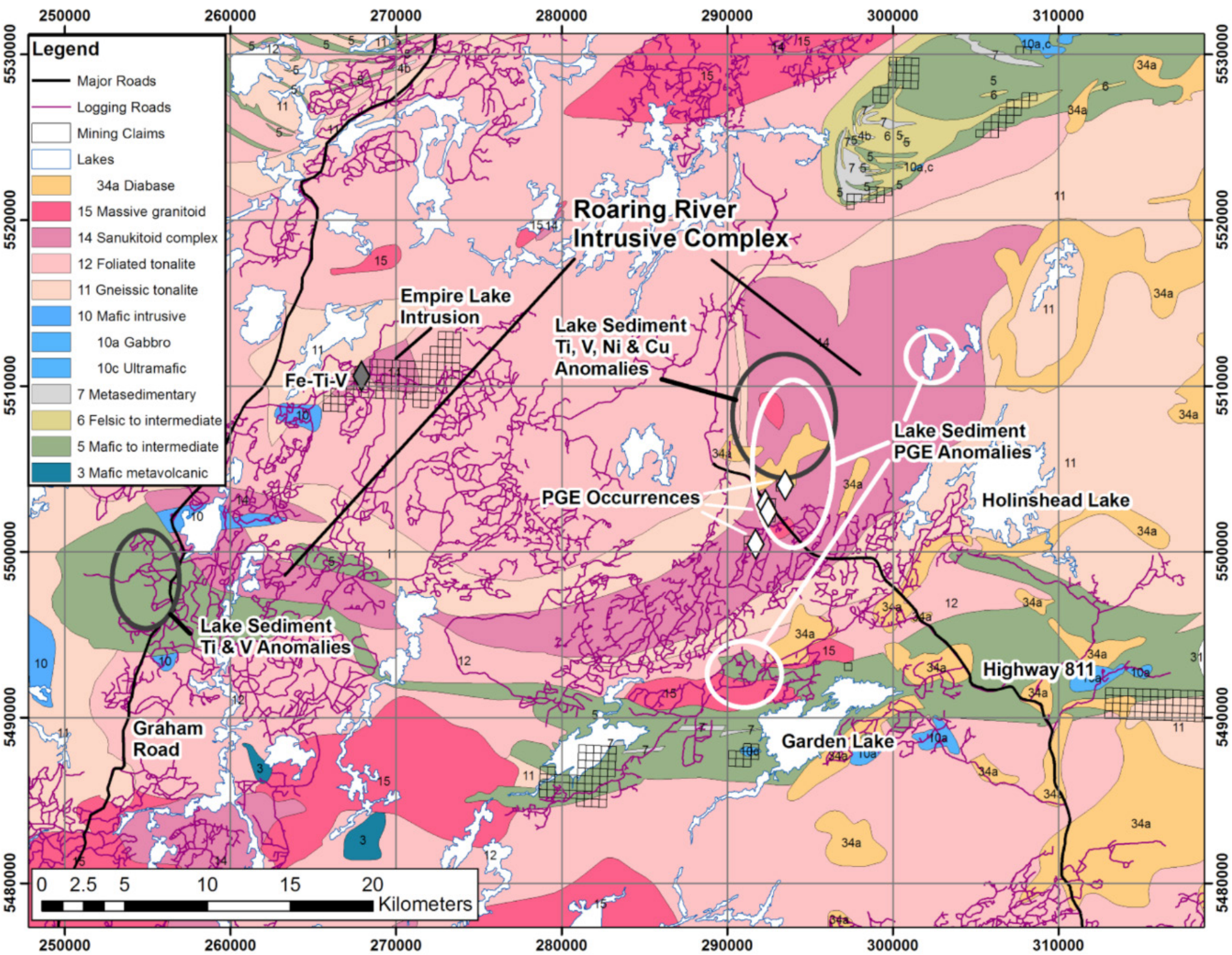

Figure 1. Geological map of the Roaring River Intrusive Complex and surrounding area showing mineral occurrences and areas with anomalous lake sediment geochemistry (geology *from* Ontario Geological Survey 2011; mineral occurrences *from* McCrindle and Fingler 2001; Schnieders et al. 2002); and lake sediment data *from* Dyer and Jackson 2000; Jackson and Dyer 2000; Ontario Geological Survey 2000).

PGE Exploration Guideline for Sanukitoid Intrusions

Stone (2010) provides the following example of PGE mineralization at the Campbell zone, in the sanukitoid-suite Entwine stock. The mineralogical characteristics of the Campbell zone can be used as a guide to assist with PGE exploration in other sanukitoid intrusions such as the RRC.

> The Campbell zone represents a 20 m wide, 1.2 km long mineralized zone within the oval western end of the Entwine stock. Although conformable with the contact, this zone occurs approximately 1 km inside the Entwine stock and is hosted by fairly homogeneous (nonlayered and nonbrecciated) diorite and leucogabbro with a mineral assemblage of plagioclase + biotite + hornblende + clinopyroxene + orthopyroxene and accessory magnetite, ilmenite, quartz, potassium feldspar, apatite and titanite. The Campbell zone is locally mineralized with a few percent chalcopyrite, pyrite, pyrrhotite, pentlandite, millerite, PGM tellurides, PGM bismuthides and electrum and assays of up to 1 g/t combined Pd+Pt+Au are common (Stone 2000). This type of PGM mineralization would likely be classified as the sulphide-poor subtype, but is notably richer in copper than nickel. Within the mineralized zone, silicates are altered to actinolite, chlorite, epidote, sericite, albite and calcite.
>
> On the basis of surface mapping, the mineralized part of the Entwine stock does not appear much different from quartz-undersaturated phases of sanukitoid plutons, except for local rusty patches caused by weathered sulphides and greenschist alteration of silicates. Using the Campbell zone as a model, Stone (2000) suggested that the somewhat complex mineralogy including 2 pyroxenes, 2 Fe-oxides and a suite of greenschist-facies secondary silicates with up to a few percent sulphides can possibly be used as an exploration tool for PGM mineralization in other sanukitoid plutons.

Lake Sediment Surveys

As mentioned above, lake sediment geochemistry surveys covering the RRC were published in 2000 (Dyer and Jackson 2000; Jackson and Dyer 2000; Ontario Geological Survey 2000). These data sets and reports identify some anomalies that are indicative of Cu-Ni-PGE and Fe-Ti-V potential in areas that are known to be either underlain, or are in close proximity to, mafic to ultramafic intrusions. These lake sediment anomalies include elevated concentrations of REE, Ti, V, W and Y in several locations near Allely Lake, at the west end of the RRC and a wide area that includes numerous Zn, Ti and Cr anomalies (including some lakes with Cu, Y, REEs, Ni, Pb, V and W anomalies) northeast of Bilkey Lake, in the eastern portion of the complex (Jackson and Dyer 2000). Significant platinum group element lake sediment anomalies also occur in 2 areas in the eastern portion of the complex (Ontario Geological Survey 2000). These anomalous areas are illustrated on Figure 1.

Geophysical Surveys

Because Fe-Ti-V mineralized zones contain considerable amounts of magnetite, it can be anticipated that they will display strong responses to magnetometer surveys. Data from an OGS regional airborne magnetic and electromagnetic survey are available as GDS 1105—Revised (Ontario Geological Survey 2003), while maps from more localized surveys are available in the Thunder Bay South District assessment files. The geophysical response of rocks over the entire RRC is illustrated on Figure 2, while Figure 3 illustrates a map from a more detailed survey completed over a historic exploration property that was centred over the mafic to ultramafic portion of the RRC that crosses the Highway 811 corridor (Bowdidge 2010). These maps illustrate a number of areas of strong magnetic response that warrant further investigation for their Fe-Ti-V mineralization potential, especially where they occur in close proximity to (or down-ice from) lake sediment anomalies.

The magnetic high southwest of Allely Lake approximately coincides with an area of anomalous Ti and V values in lake sediment. It also appears to occur in the area where a geochronology sample of gabbroic anorthosite was collected by Stone et al. (2002). This sample is the same age and rock type as a sample that was collected from the Empire Lake intrusion. Based on this information, this area is considered to be an excellent target for Fe-Ti-V exploration.

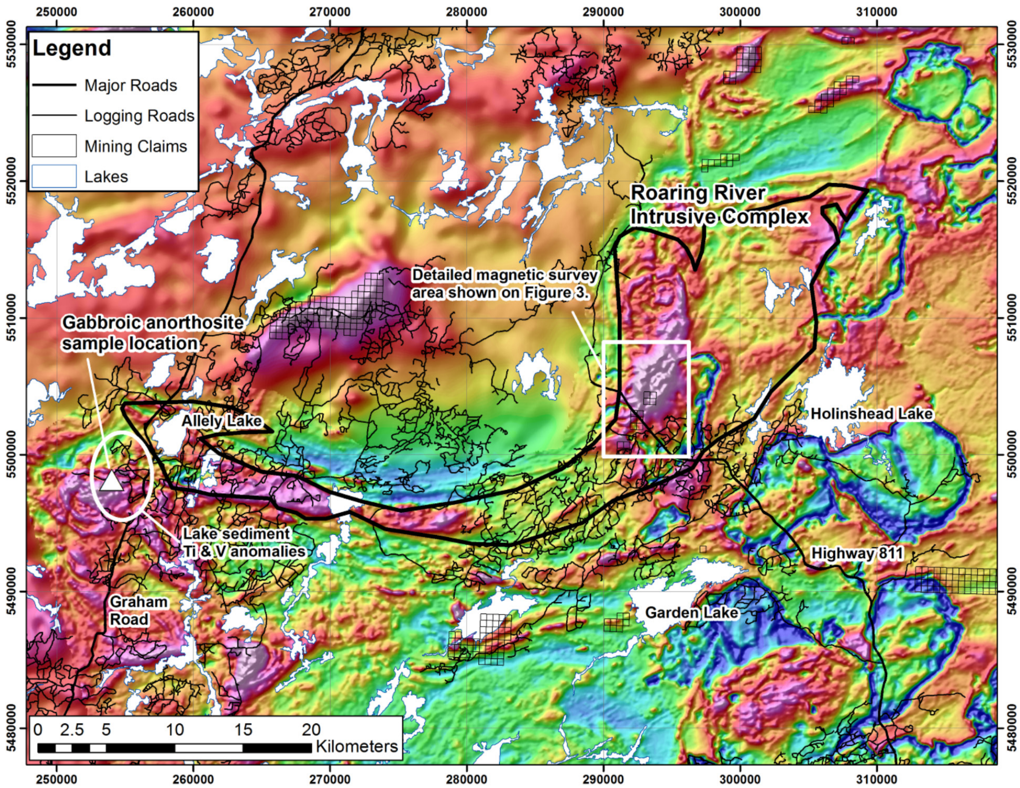

Figure 2. Residual total field magnetic map (data *from* Ontario Geological Survey 1999 and 2003) of the Roaring River Intrusive Complex (outlined in black) and surrounding area. Areas of highest magnetic response are illustrated in pink.

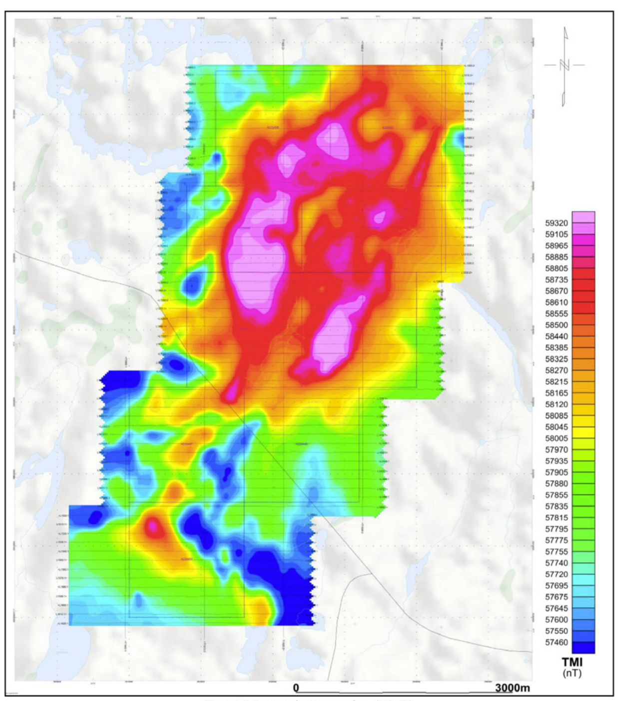

Figure 3. Total magnetic intensity map *from* Bowdidge (2010) for the mafic to ultramafic portion of the Roaring River Intrusive Complex that is bisected by Highway 811. Areas with the highest magnetic response are shown in pink.

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HIGHLIGHTS

- **Lithium anomalies in lake sediment associated with a muscovite granite intrusion south of Frazer Lake indicate potential for the discovery of lithium-bearing pegmatites**
- **Prospecting for lithium-bearing pegmatites is also warranted near a granitic intrusion at the south end of Wolf Lake whose location coincides with an area with numerous lake sediment lithium anomalies**
- **Numerous gold anomalies in lake sediment indicate potential for the discovery of iron oxide-copper-gold (IOCG)-type mineralization in the Dorion area**

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Exploration Potential in the Nipigon Embayment North of Dorion

The portion of the Nipigon Embayment between Dorion and Lake Nipigon has seen modest amounts of mineral exploration activity since the late 1800s, chiefly for vein-hosted lead-zinc (Pb-Zn), unconformity-type uranium (U), and mafic to ultramafic intrusion-hosted copper-nickel-platinum group elements (Cu-Ni-PGE) deposits. Other commodities that have been targeted include marl and dimension stone. Based on Thunder Bay South District mineral deposit and assessment file records, the primary periods of exploration interest for these commodities have been as follows.

- Lead-Zinc (Pb-Zn): 1888-1907, 1948-50, 1982-84.
- Uranium (U): 1976-82, 2007-09.
- Copper-Nickel-Platinum Group Elements (Cu-Ni-PGE): 1999-2002, 2009-2014.
- Marl: 1959-60.
- Dimension Stone: pre-1913.

The area has also seen some past production of lead-zinc and dimension stone. In 1903, the Dorion lead and zinc mine produced 317.5 tonnes of ore grading 20% Zn and 10% Pb, while the Wolf River sandstone quarry produced dimension stone in the first half of the 20th century during the years 1913–15 and 1921–31.

The locations of mineral occurrences documented in the Ontario Geological Survey (OGS) Mineral Deposit Inventory (MDI) database (Ontario Geological Survey 2018) are summarized in Table 1 and illustrated on Figures 1 and 2. The occurrences are labelled according to commodity on Figure 1 and MDI number on Figure 2. Note that many of these occurrences, including the Dorion lead and zinc mine, are currently open for staking.

While the Dorion area has well-established potential for the commodities listed above, little attention has been given to the area’s rare-metal (most notably lithium) or gold potential. Information available in OGS publications and mineral exploration assessment files suggest that future exploration programs north of Dorion should pay greater attention to these commodities.

Table 1. Mineral occurrences north of Dorion (Ontario Geological Survey 2018). Co-ordinates are provided in UTM NAD 83, Zone 16. Occurrences that were available for staking on November 30, 2018 are highlighted in bold.

Name	Classification	Commodities	MDI	Easting	Northing
Acker, W.	**Occurrence**	**Zinc, lead**	**MDI52A15SE00022**	**373927**	**5412925**
Andowan Group 9	Occurrence	Lead	MDI52A15SE00016	380975	5408628
Bishop	**Occurrence**	**Lead**	**MDI52A15SE00021**	**378152**	**5411005**
Black Sturgeon Halite	**Occurrence**	**Salt**	**MDI000000001140**	**362700**	**5465401**
Black Sturgeon SE	**Discretionary occurrence**	**Iron**	**MDI52H07SE00002**	**378155**	**5460085**
Canyon	**Occurrence**	**Uranium**	**MDI000000001144**	**369901**	**5463598**
Dorion Mine	**Developed prospect w/o reserves**	**Lead, zinc**	**MDI52A15SE00003**	**377402**	**5410500**
Driftstone Copper	Discretionary occurrence	Copper	MDI52A16NW00007	390135	5423168
Float	Discretionary occurrence	Copper	MDI52A16NW00005	390060	5416013
Foxden	**Occurrence**	**Nickel, copper**	**MDI52A16NW00006**	**386664**	**5420323**
Gresky	**Occurrence**	**Marl**	**MDI52H02SE00002**	**378525**	**5437255**
Roland Lake	**Discretionary occurrence**	**Uranium, thorium**	**MDI000000001143**	**384418**	**5458265**
Santack	**Occurrence**	**Lead**	**MDI52A15SE00015**	**373702**	**5412665**
Split Rapids Dam	Occurrence	Uranium	MDI000000001132	369218	5466834
Stirling	Discretionary Occurrence	Zinc, lead	MDI52A15SE00009	382870	5413116
Tessier–Williamson	**Occurrence**	**Uranium**	**MDI52H01SW00002**	**391015**	**5428877**
Thunder Bay	Occurrence	Lead	MDI52A15SE00002	379315	5411399
Wolf River Sandstone Quarry	Developed prospect w/o reserves	Sandstone	MDI52A15SE00025	383359	5411908

Lithium Potential near Mound and Wolf Lakes

Hart (2005) mapped a muscovite granite intrusion south of Frazer Lake (*see* area of lithium potential shown on Figure 1) and described it as follows.

> The pegmatitic, muscovite leucogranite body and dikes located east of the Black Sturgeon River contain intergrowths of tourmaline and quartz, and muscovite and quartz commonly observed in rocks that have been classified as fertile granites, or granites that have the potential to host rare-element mineralization (Breaks, Selway and Tindle 2003). Additional work is required to characterize these bodies. The muscovite leucogranite occurs along the regional trend extending from Georgia–Barbara lakes area in the northeast to the DeCourcey Lake and Onion Lake areas in the southwest (Breaks, Selway and Tindle 2003), and this area may represent a similar concentration of fertile granites. The fact that these bodies have been examined in only a cursory manner during this mapping program means that additional prospecting is recommended in the area between Mound Lake and the natural gas pipeline.

Additional data that reinforce the rare-metal potential of this intrusion are provided in a lake sediment survey report (Dyer and Russell 2002) that highlights lithium anomalies in a number of lakes located within and adjacent to the intrusion. Most of the sample sites in this area that showed elevated lithium values occur along a north-trending fault zone that can be seen passing through the muscovite granite intrusion on Figure 1.

Another area with a substantial number of lithium anomalies in lake sediment (Dyer 2002; Dyer and Russell 2002) approximately coincides with a biotite granite intrusion (Hart 2005) that occurs near the south end of Wolf Lake (second area of lithium potential shown on Figure 1). Based on this information, prospecting for lithium-bearing pegmatites is warranted in the vicinity of this intrusion.

Gold (and Copper) Potential Between Wolf and Roland Lakes

A number of gold anomalies in lake sediment have been noted by Dyer and Russell (2002) in the area between Wolf and Roland lakes (*see* Figure 1). These anomalies appear to have garnered little attention, most likely because they are not located in areas with geology that is considered to be favourable for Archean lode gold deposits (i.e., greenstone belts). Nevertheless, this is an area that has previously been noted to have potential for the discovery of Proterozoic iron oxide-copper-gold (IOCG)-type mineralization (i.e., Schnieders et al. 2002; Smyk and Franklin 2007). As discussed below, anomalous gold mineralization has been documented in association with Proterozoic rocks at a number of localities in the Nipigon Embayment, reinforcing the gold exploration potential of this area.

Hart (2005) has noted that anomalous gold concentrations occur at several locations in the Nipigon Embayment. At one location, gold occurs with pyrite, chalcopyrite, magnetite, ilmenite, galena and silver at a diabase sill contact (Rogala 2001). Data provided with an assessment report for a uranium exploration program carried out to the south of Frazer Lake (Sims 2007), also indicates the presence of anomalous gold (up to 201 ppb Au) in samples of silicified mafic intrusive rocks containing pyrite and chalcopyrite mineralization (UTM Zone 16, 388217 mE, 5445150 mN). Most notably, assays of up to 0.33 ounces gold per ton have been reported at the Enterprise Mine (a Proterozoic quartz-carbonate vein-hosted lead-copper-silver-gold deposit), 13 km southwest of Dorion, where the gold is associated with chalcopyrite (Tanton 1931).

Exploration near the lake sediment gold anomalies should focus on the investigation of any quartz-carbonate veins and breccia zones, especially those that are mineralized with chalocopyrite and/or hematite (i.e., hematite is associated with IOCG systems). Prospecting for such features should focus on areas near mapped faults (*see* Figures 1 and 2), and especially in the vicinity of intersecting faults. Contact zones near the base of diabase sills should also be examined for signs of veining, sulphide mineralization and alteration, as the diabase intrusions could have acted as physical traps for gold-bearing fluids.

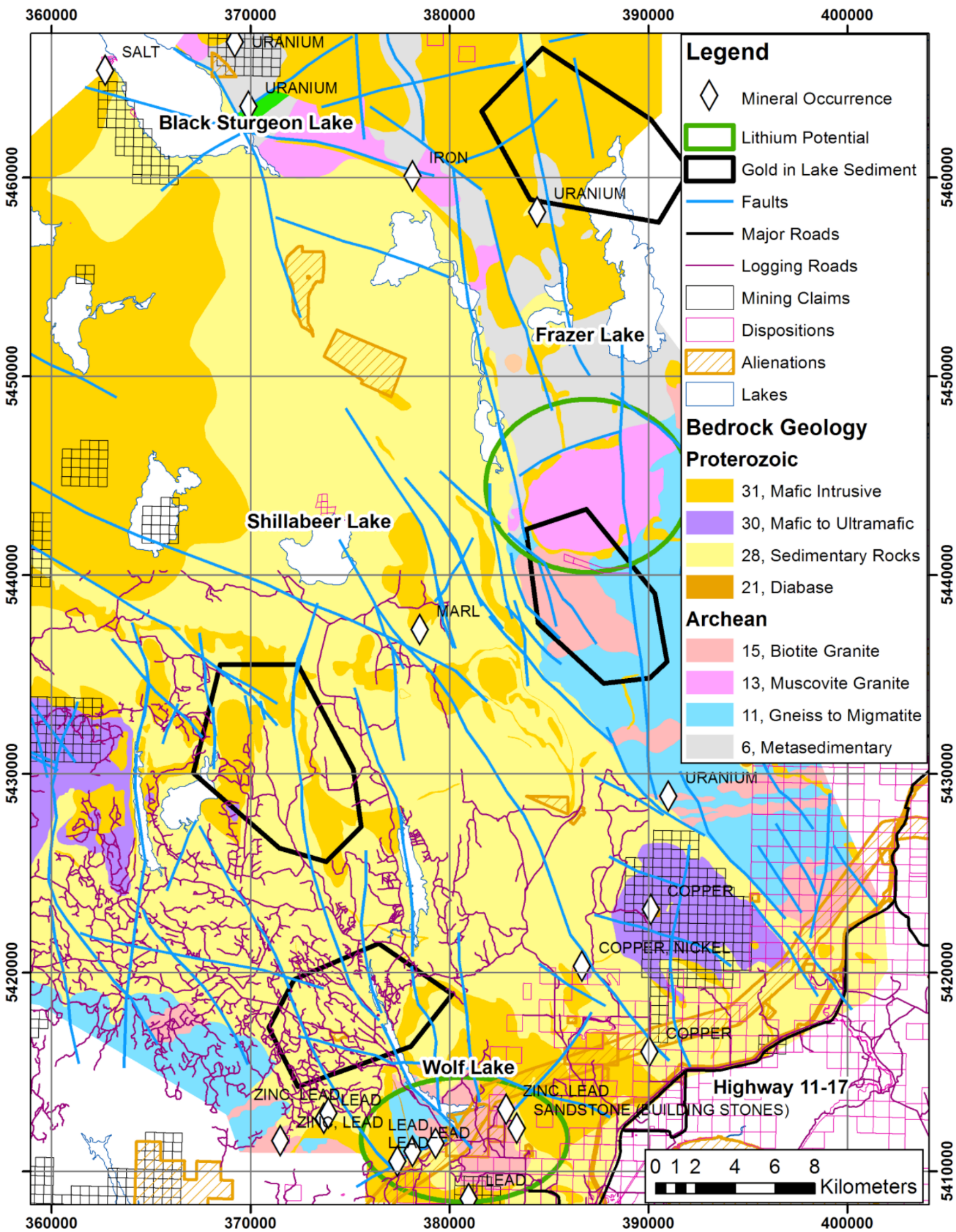

Figure 1. Geology of the area north of Dorion with mineral occurrences and areas recommended for gold (IOCG) and lithium exploration (geology *from* Izumi, 2006). Map grid is provided in UTM NAD83 Zone 16 co-ordinates.

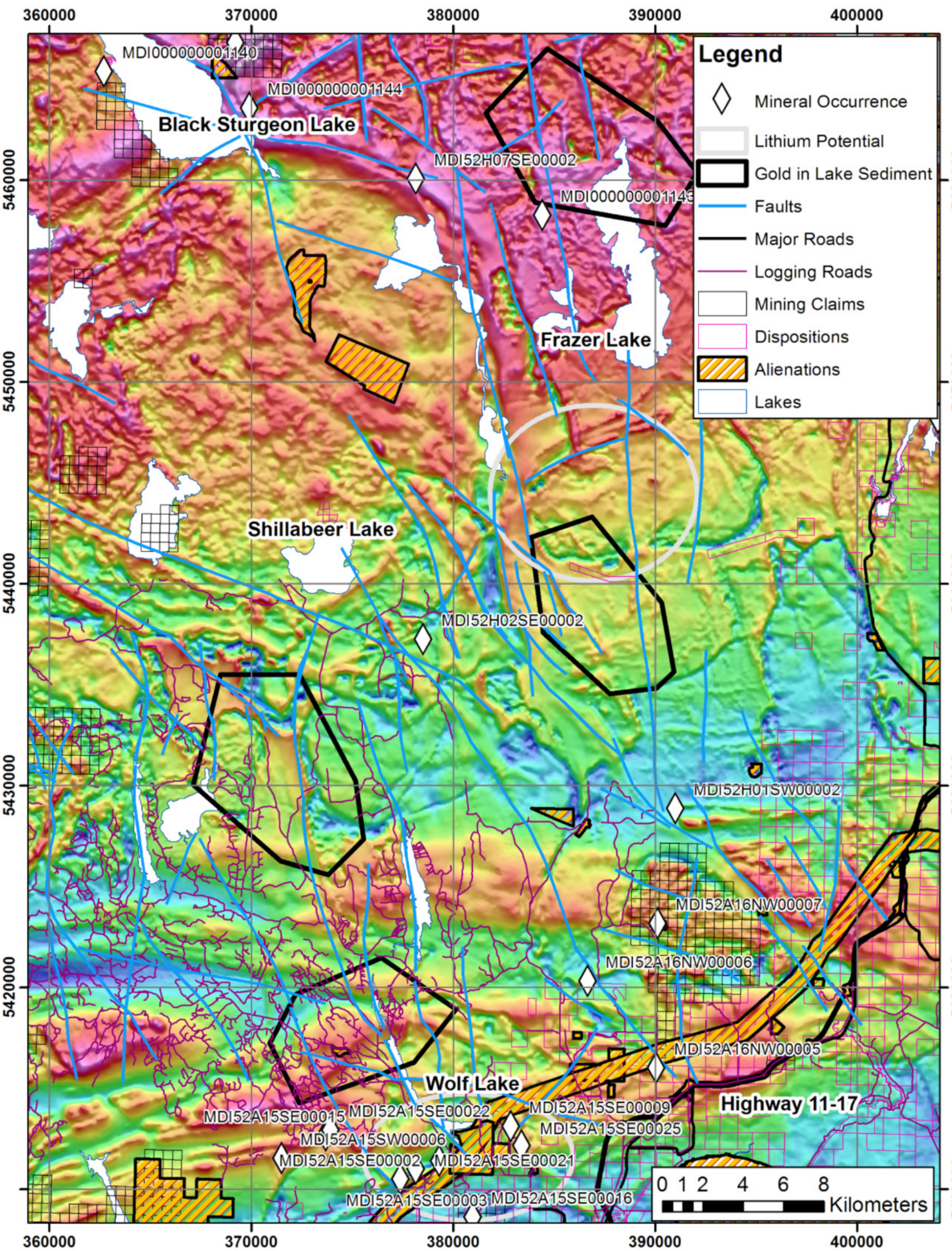

Figure 2. Geophysical map of the area north of Dorion with mineral occurrences and areas recommended for gold (IOCG) and lithium exploration (geophysical data *from* Ontario Geological Survey 2004, 2015). Map grid is provided in UTM NAD83 Zone 16 co-ordinates.

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HIGHLIGHTS

- **Musselwhite Mine (Goldcorp Canada Ltd.) completed a soil sampling program in 2014**
- **Several anomalous gold values were found during this soil sampling program, including showings of 12 ppb and 36 ppb Au**
- **Temiskaming-type (~2681 Ma) sediments in the Heaton Lake area make it prospective for gold mineralization**
- **Totogan shear extends east-west in this area adding potential for mineralization**

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Gold Potential East of Musselwhite Mine

The Heaton Lake area (Figure 1) is underlain by Temiskaming-type Archean age metasediments (approximately 2681 Ma; Duff 2014) which is similar in age and type to gold camps throughout Ontario, making it prospective for gold mineralization. The Totogan shear extends east-west through this area, adding to the potential for gold mineralization. Musselwhite Mine's exploration department completed a soil sampling survey on their Heaton Lake Project in 2014, which consisted of 23 claims located in Karl Lake, Dusten Lake, Schryburt Lake, Forester Lake, Neawagank Lake, and Pineimuta River Areas (Biczok 2015). The claims have since lapsed and at the time of writing (December 27, 2018) are currently open for staking. The program consisted of 426 humus and 118 red sand samples taken at 25 m intervals along 100 m north-south lines (Figure 2). Several anomalous gold and arsenic values were found through this sampling project, with gold ranging from less than 1 ppb to a maximum of 36 ppb. The 36 ppb Au sample was not replicated and the next highest value was 12 ppb. Although orogenic gold pathfinder elements (As, Ba, Co, La, Mo, Sb, Zn) were not clustered in an array that suggests correlation, further work is recommended to determine whether there is mineralization at depth as indicated by anomalous gold found in the soil samples.

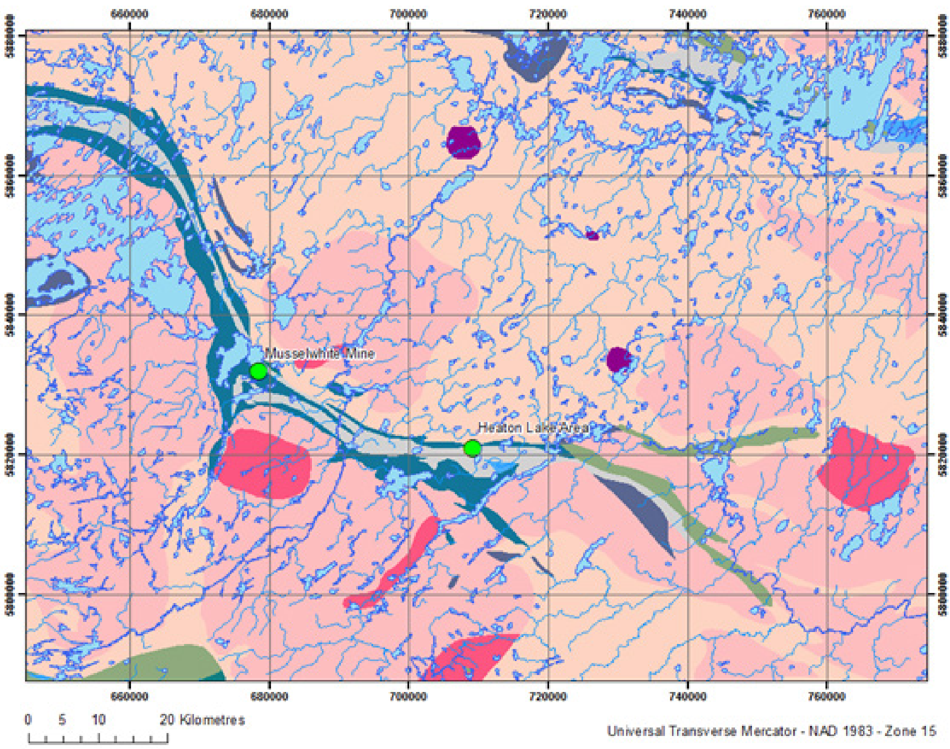

Figure 1. Map showing the location of the Heaton Lake area in northwestern Ontario over bedrock geology (*after* Ontario Geological Survey 2011).

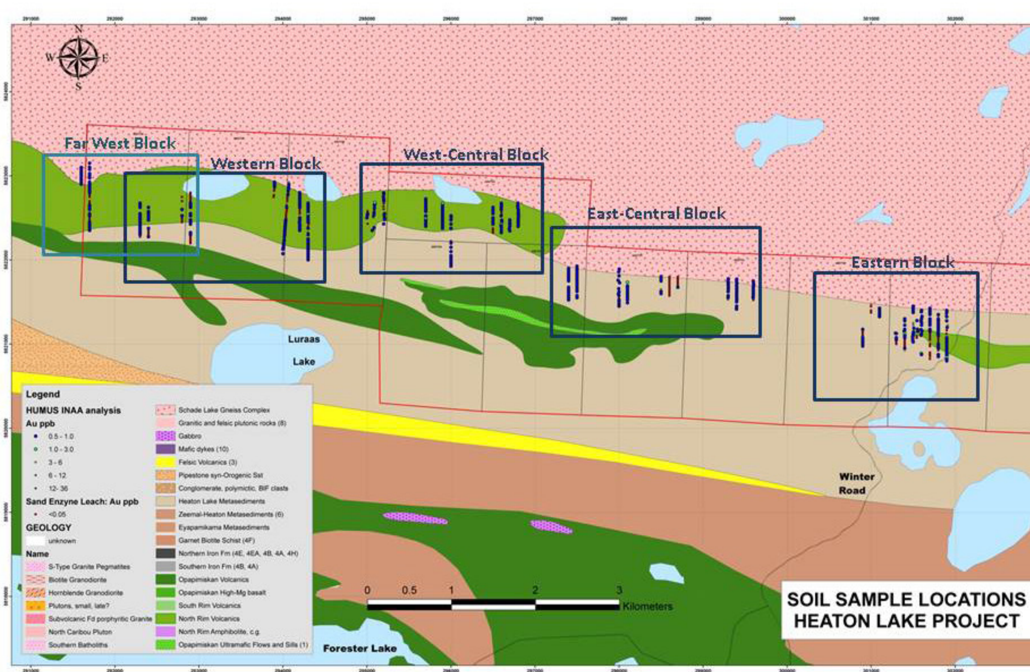

Figure 2. Map shows the layout of the sampling blocks used in the Heaton Lake area soil survey (Biczok 2015).

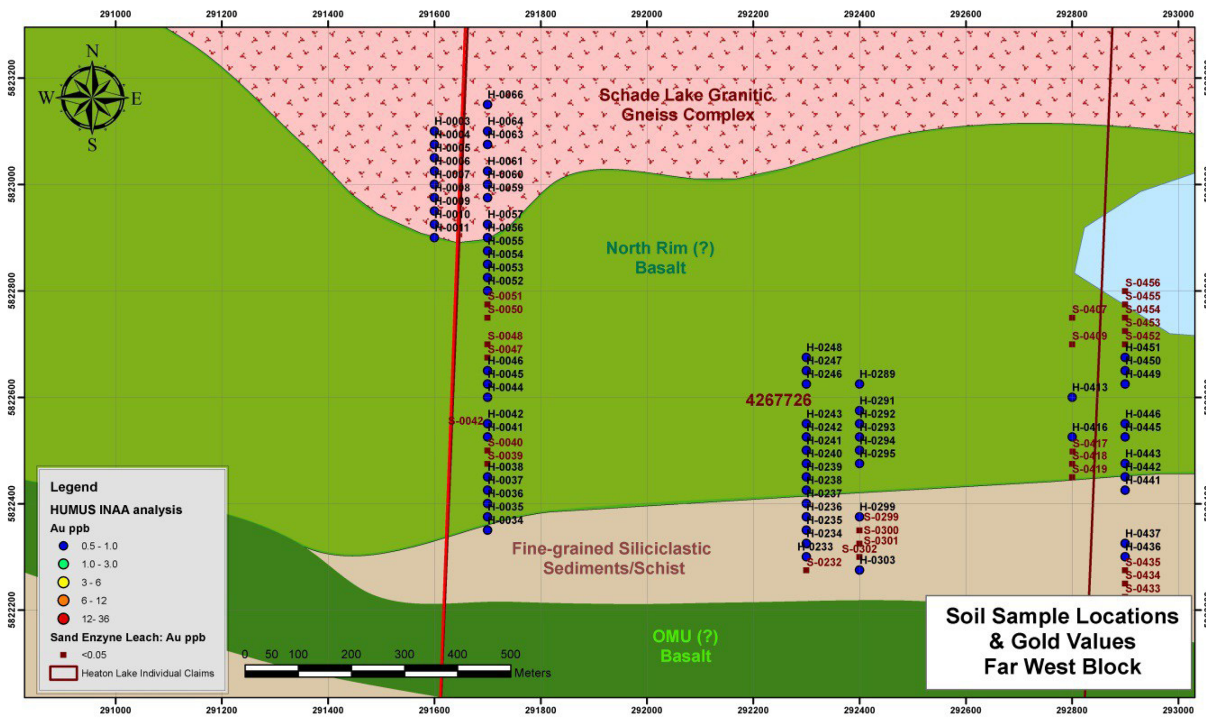

Figure 3. Heaton Lake area soil sample locations and gold values for the far western block (Biczok 2015).

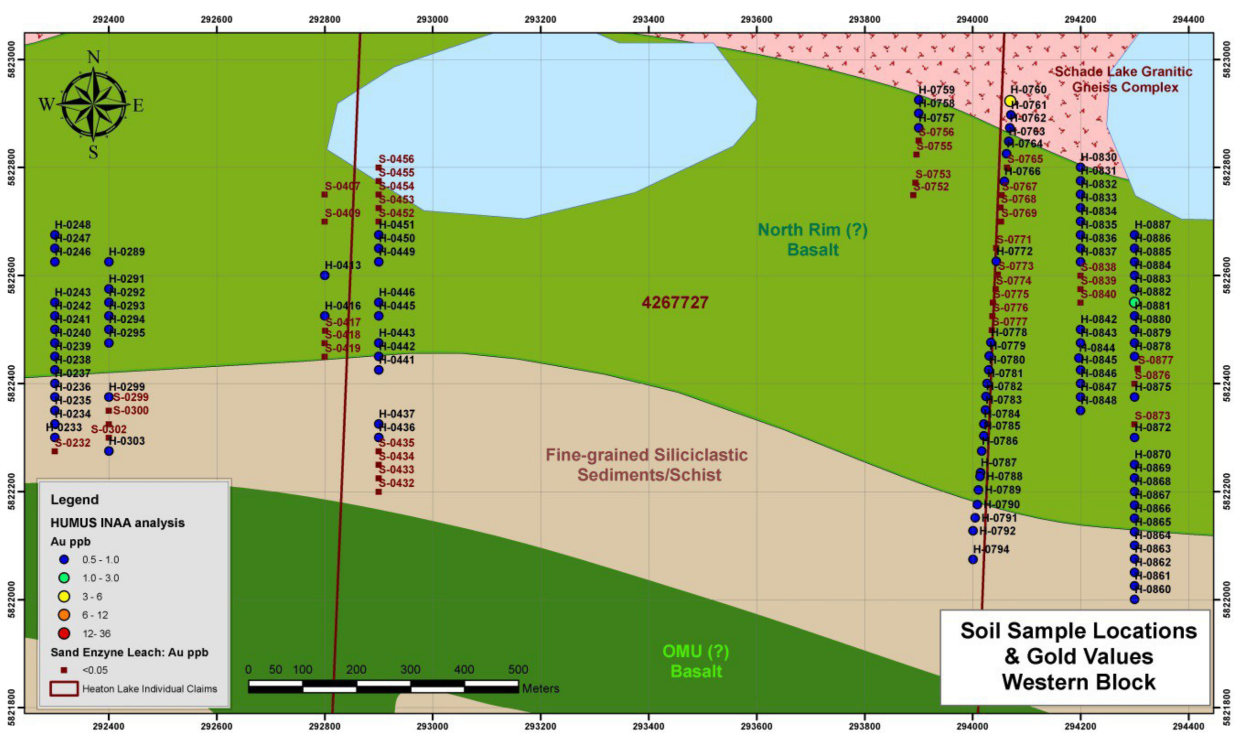

Figure 4. Heaton Lake area soil sample locations and gold values for the western block (Biczok 2015).

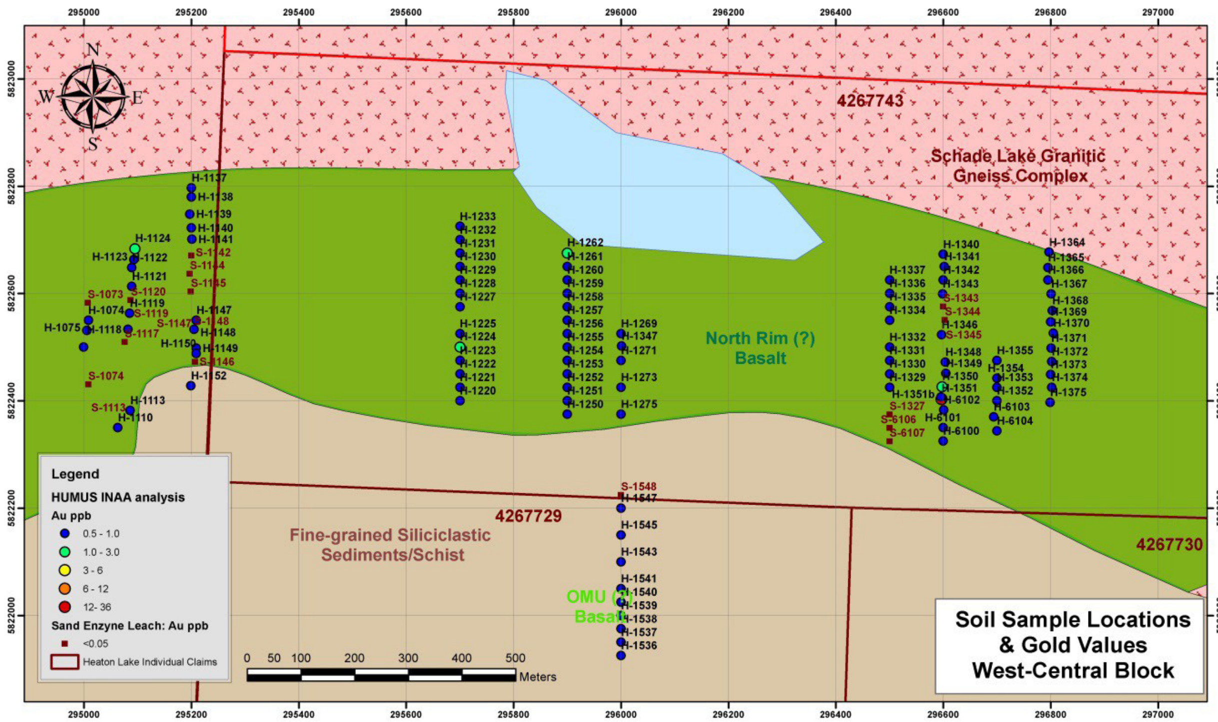

Figure 5. Heaton Lake area soil sample locations and gold values for the west-central block (Biczok 2015).

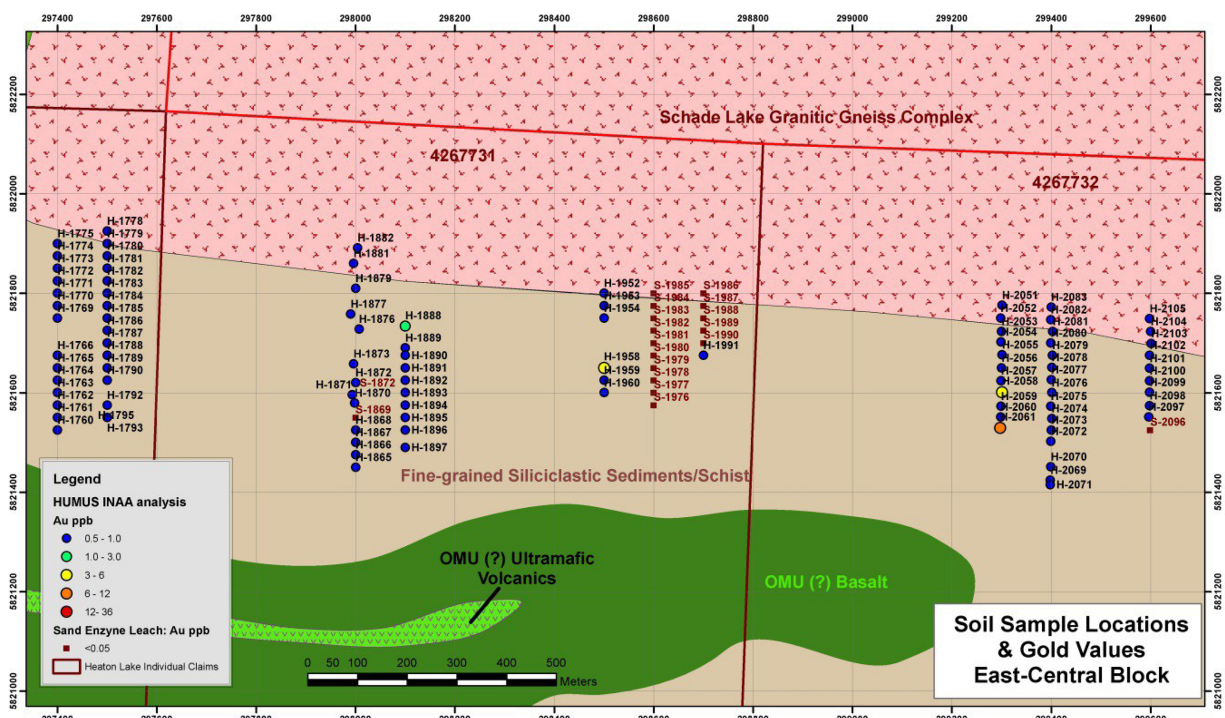

Figure 6. Heaton Lake area soil sample locations and gold values for the east-central block (Biczok 2015).

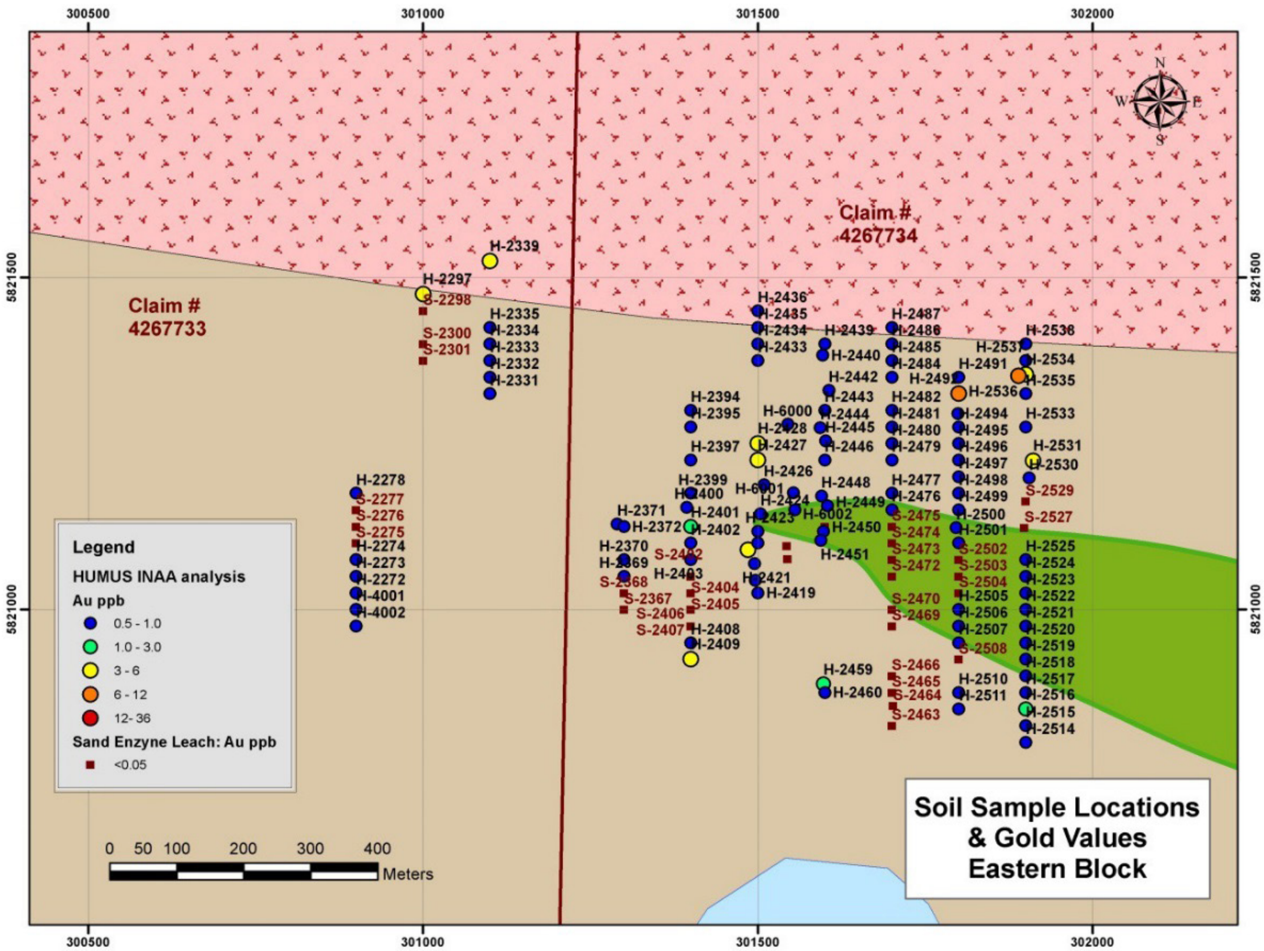

Figure 7. Heaton Lake area soil sample locations and gold values for the eastern block (Biczok 2015).

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HIGHLIGHTS

- **Large, under-explored land packages open for acquisition in the prolific Beardmore–Geraldton greenstone belt**
- **New and old surficial data indicate high potential for undiscovered gold mineralization west and immediately north of the multi-million-ounce Hardrock deposit**

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New Frontiers in the High-Potential Beardmore-Geraldton Greenstone Belt

The Beardmore–Geraldton greenstone belt (BGGB) has been subject to considerable production and exploration over the past century, yet large areas still remain relatively untested for gold mineralization. A growing trend in the mineral sector is the acquisition and exploration of large land packages, especially those overlooked in prolific areas of high mineral potential. Limiting factors such as overburden, remoteness and/or land tenure limitations may apply to such areas which have resulted in limited exploration activity. This article presents 2 opportunities in the Beardmore–Geraldton greenstone belt based on re-thinking of old ideas as well as recently released and historical surficial data sets: the Clist–Goldfield corridor and the Atigogama–Margo corridor.

The iron formation in the southern part of the BGGB, between Clist Lake and Goldfield Lake, has been subject to minimal exploration despite its location immediately west of the Geraldton gold camp, host to the multi-million-ounce Hardrock deposit. Recently released lake sediment data (Handley and Dyer 2018) has revealed one significant gold anomaly (36 ppb Au from sample 11-RDD-0050) from a waterbody approximately 2.5 km south-southeast of Patsy Lake (Figure 1). The bedrock source of the lake sediment gold anomaly is inferred to originate from directly north near Patsy Lake, possibly from the Patsy Lake occurrence.

Staff of the Resident Geologist Program in the Thunder Bay District office visited the Patsy Lake occurrence in the summer of 2018. An outcrop area approximately 2500 m^2 was investigated and found to contain carbonatized and silicified siltstone to greywacke with up to 5% sulphides (pyrite). Folded and boudinaged quartz veins were also observed at several locations. Outcrops of oxide facies iron formation were also investigated on Leopard Lake Rd. south of the Patsy Lake occurrence. Very little sulphide replacement was observed at these locations but it should be noted that gold mineralization associated with sulphide replacement in iron formation has been noted at the Lattimer occurrence approximately3.5 km west-southwest of the Patsy Lake occurrence (Table 1). Drilling by C. Lattimer in 1949 indicated one intersection of 8.16 oz/ton gold over 0.49 m (Lattimer 1949). Although the Lattimer occurrence is not open for acquisition at the time of publication, the presence of sulphide replacement gold mineralization in iron formation in this part of the BGGB highlights the potential for the southern part of the BGGB to host additional, undiscovered gold mineralization. Assay results from samples taken in the 2018 field season are pending.

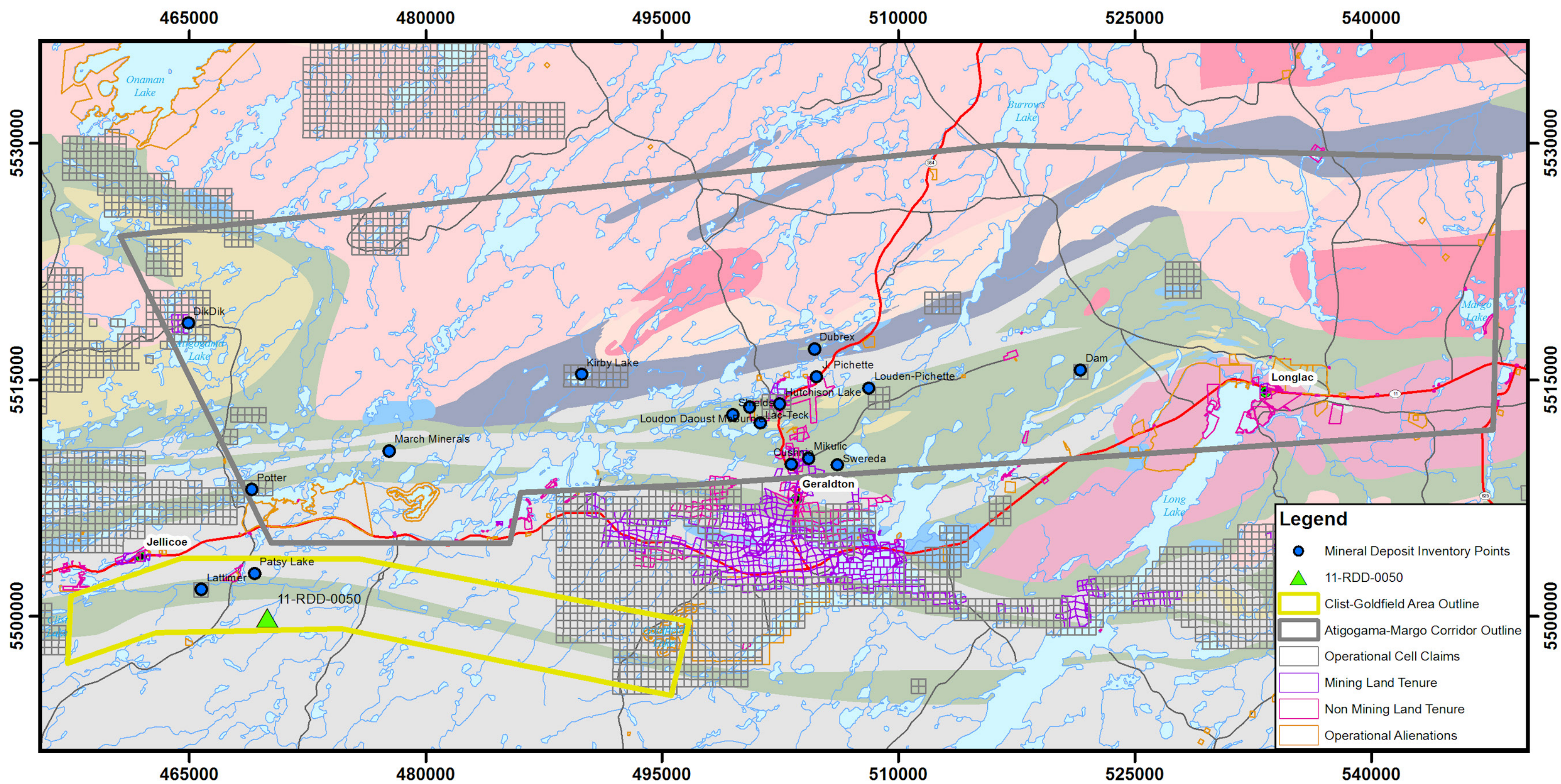

Figure 1. Geological map showing the location of the Atigogama–Margo corridor (boxed in grey) and the Clist–Goldfield corridor (in yellow). Universal Transverse Mercator (UTM) co-ordinates are provided using North American Datum 1983 (NAD83) in zone 16; regional geology *from* Ontario Geological Survey (2011). Claim units current to December 3, 2018.

Table 1. Summary of occurrences in the Atigogama–Margo and the Clist–Goldfield corridors (excluding peat and non-metals; data *from* Ontario Geological Survey 2018).

Occurrence/Prospect	Classification	Mineral Deposit Inventory (MDI) number	Mineral Tenure	Primary Commodity
Atigogama–Margo Corridor				
DikDik Mine	Past-producing mine with reserves	MDI42E14SW00002	acquired	gold
Potter	Discretionary occurrence	MDI42E11NW00003	acquired	gold
March Minerals	Discretionary occurrence	MDI42E11NW00002	open	gold
Kirby Lake	Occurrence	MDI42E14SE00004	acquired	zinc
Loudon Daoust McBurnie	Occurrence	MDI42E14SE00005	open	gold
Shields	Occurrence	MDI42E15SW00007	alienation	gold
Lac-Teck	Discretionary occurrence	MDI42E15SW00008	open	gold
Hutchison Lake	Developed mineral prospect without reserves	MDI42E15SW00002	acquired	gold
J. Pichette	Occurrence	MDI42E15SW00014	open	zinc
Dubrex	Discretionary occurrence	MDI42E15SW00009	open	gold
Louden–Pichette	Occurrence	MDI42E15SW00011	acquired	zinc
Cushnie	Occurrence	MDI42E10NW00025	open	gold
Mikulic	Discretionary occurrence	MDI42E10NW00027	open	gold
Swereda	Discretionary occurrence	MDI42E10NW00028	open	gold
Dam	Occurrence	MDI42E15SE00007	acquired	gold
Clist–Goldfied Corridor				
Lattimer	Occurrence	MDI42E11NW00004	acquired	gold
Patsy Lake	Occurrence	MDI42E11NW00005	open	gold

The Atigogama–Margo corridor is a large area approximately 90 km in length covering the northern boundary of the BGGB from Atigogama Lake to Margo Lake (*see* grey outline *in* Figure 1). The area has long been recognized to have high mineral potential but has not been subjected to the same level of mineral exploration as the rest of the BGGB due to the large amount of glacial till cover. Consequently, there are relatively few documented mineral occurrences or showings in the Mineral Deposit Inventory (Ontario Geological Survey 2018) within this area which is a reflection of the lack of historical mineral exploration, and not necessarily of poor mineral potential (*see* Figure 1).

The Paint Lake shear zone (PLSZ) is a high-strain zone, approximately 500 m wide, at or near the northern boundary of the BGGB (Mackasey 1976). The Atigogama–Margo corridor covers the eastward extension of the PLSZ, which is poorly constrained in this part of the BGGB as it is largely covered by overburden (LaFrance, deWolfe and Stott 2004). Subsequently, the extent of the northern boundary of the BGGB is interpreted by the total residual magnetic field signature (Figure 2; Ontario Geological Survey 1999, 2003a, 2003b). The Brookbank gold deposit, located approximately 20 km west of the target area, is hosted within the "Brookbank Shear Zone" which is interpreted to be a structural splay off the PLSZ. A similar geological setting is likely to be present in the Atigogama–Margo corridor where splays off the east extension of the PLSZ are likely and would provide a favourable structural setting for gold mineralization. Exploration targeting should not be limited to the metavolcanic and metasedimentary rocks of the BGGB but should also include granitoid rocks present to the north of the BGGB. Gold deposits in the Atikokan area (i.e., Marmion Lake and Bedivere Lake) can be used as an analogue for gold mineralization hosted in granitoid rocks and controlled by splays off a major crustal suture (cf. Poulson 2000; Puumala et al. 2016). The MDI data available in the Atigogama–Margo corridor are presented in Table 1.

Locally thick and extensive deposits of till have been documented in the Atigogama–Margo corridor with till thicknesses of up to 60 m recorded from sonic drilling (Thorleifson and Kristjansson 1988). Subsequently, conventional mineral exploration methods have been largely impeded by thick till cover in this area. Kristjansson, White and Sado (1988) and Kristjansson, Gaudino and White (1989) noted that the lithological composition of the gritty, silty, sand till is dominated by rock types of local provenance. In areas of thicker till, the gritty, silty, sand till is overlain by fine-grained calcareous till, the former variety represents an excellent sampling medium for till geochemistry programs. Thorleifson and Kristjansson (1988) suggest that in areas of thin and discontinuous till, surface samples appear to contain locally derived material located in an up-ice flow direction. In areas of thick till, surface samples lack a detectable local component and are dominated by fine-grained calcareous till. Thorleifson and Kristjansson (1987) revealed several gold grains in till from the Atigogama-Margo corridor, which were interpreted to be derived from locally sourced till material (Figure 3). Results were dispersed due to both sample density and variable till thickness but the presence of gold grains in till from the target area supports the high mineral potential interpreted for the Atigogama–Margo corridor. Furthermore, Kristjansson, White and Sado (1988) and Kristjansson, Gaudino and White (1989) note distinct similarities between the till varieties described in the study area to the till sequence defined surrounding the Hemlo gold camp, which suggests that the frame work for exploration geochemistry developed at Hemlo is directly applicable to the target area (cf. Geddes and Kristjansson 1986).

Overburden drilling techniques may be applied to yield locally derived material at the base of the till sequence. Advanced surficial sampling techniques such as Mobile Metal Ions (MMI™) surveys should also prove useful in targeting gold mineralization in areas of deep cover. Additionally, biogeochemical programs may also prove useful in delineating specific target areas from a large land package.

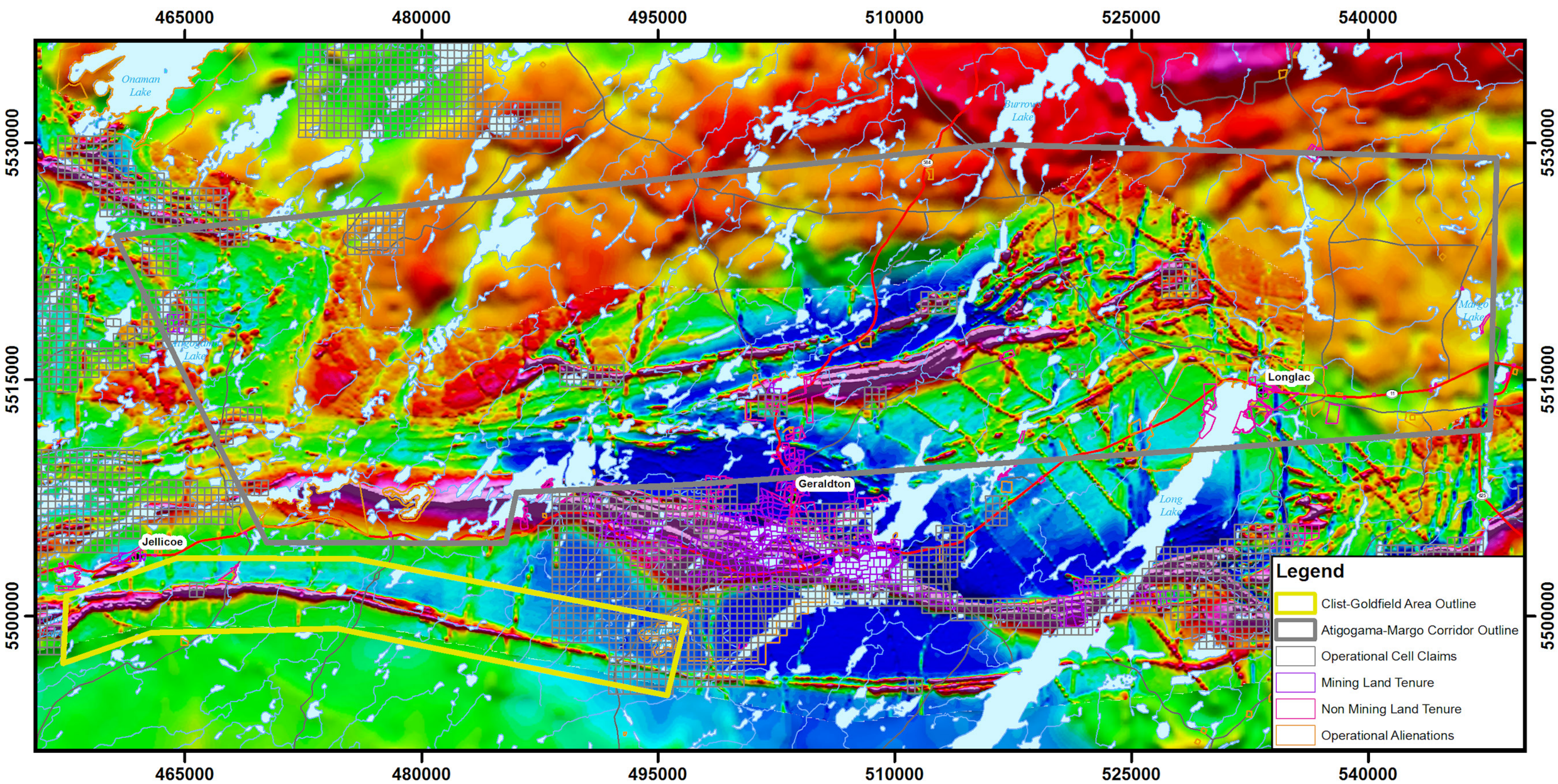

Figure 2. Atigogama–Margo corridor (grey) and the Clist–Goldfield corridor (yellow) overlie the image of the total residual magnetic field. Geophysical data *from* Ontario Geological Survey (1999, 2003a, 2003b); UTM co-ordinates in NAD83, Zone 16. Claim units current to December 3, 2018.

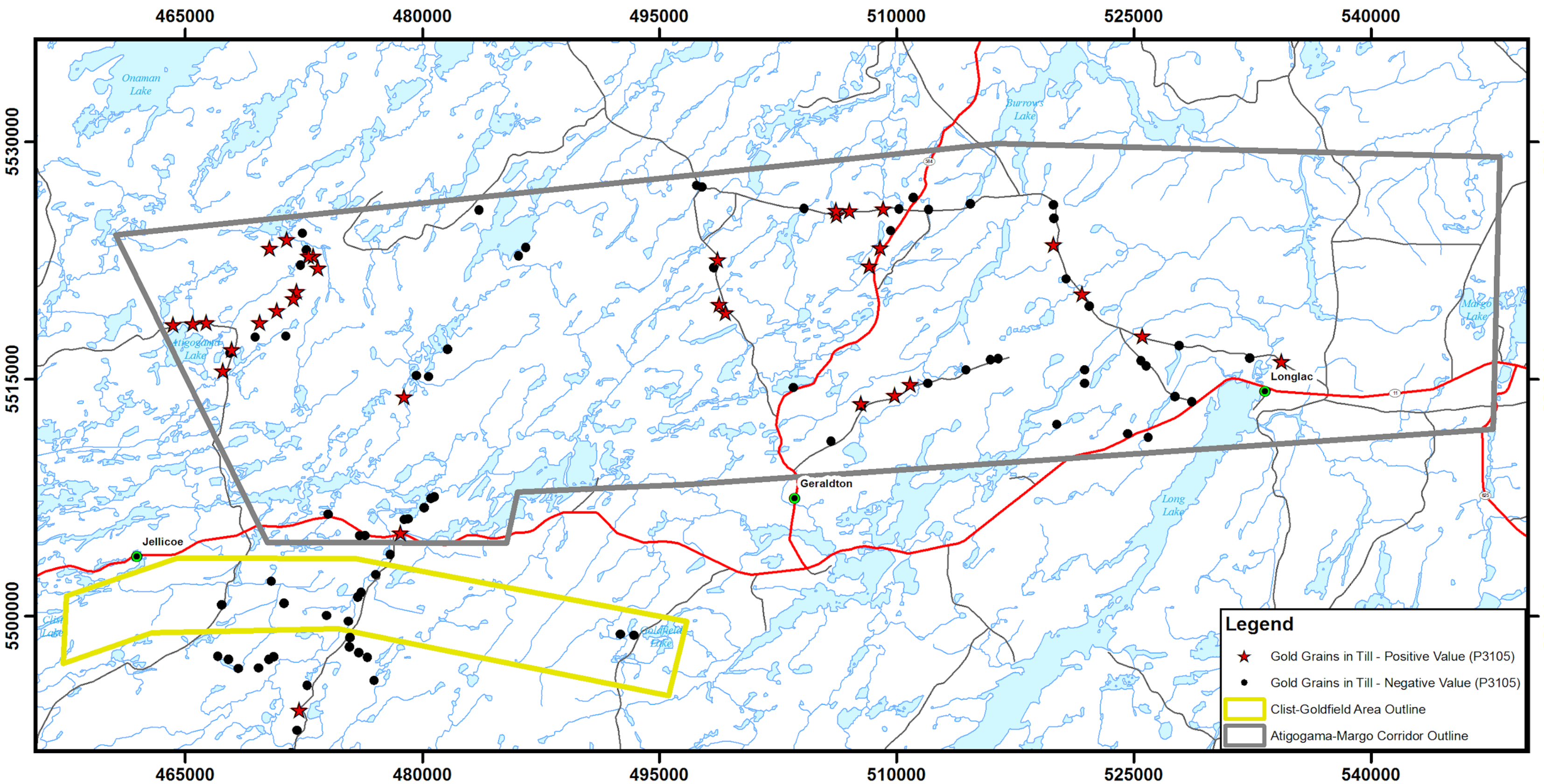

Figure 3. Gold grain counts in till for sample locations in the Atigogama–Margo corridor (grey) and the Clist–Goldfield (yellow) corridor (data *from* Thorleifson and Kristjansson (1987)).

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HIGHLIGHTS

- **Greenstone area has seen little to no historical exploration for lithium-rich pegmatites or pegmatites in general**
- **No known rare earth metal or rare earth element MDI location near lake sediment anomalies**
- **Numerous lithium and cesium lake sediment anomalies**

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Beardmore to Geraldton: Lithium in a Prolific Gold Camp

Historical exploration activity in the Beardmore–Geraldton and Onaman–Tashota greenstone belts in northwestern Ontario has focused on precious and base metals. Due to the continued demand for electric cars, mobile devices and 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 need to be discovered. Here we highlight 5 grassroots areas in the Beardmore–Geraldton greenstone belt that may have the potential for lithium based on lake sediment anomalies. At the time writing, all 5 areas were available for online claim registration.

1. Frank Lake
2. Humbolt Bay
3. North Wind Lake
4. Burrows Lake
5. Quetico Target

The data presented is based on the recently released lake sediment data from the Greenstone area collected by the Ontario Geological Survey (OGS) (Handley and Dyer 2018), and information from the OGS Resident Geologist Program (RGP) Mineral Deposit Inventory (MDI) online database. The raw data and the interpreted anomalies are not proximal to any known rare earth element or rare metal occurrence in the MDI (Ontario Geological Survey 2018).

Only, lithium (Li) and cesium (Cs) data were considered as lithium-cesium-tantalum (LCT) pegmatites are targeted. Both the deep (Figure 1) and shallow (Figure 2) lake sediment geochemistry show similar anomaly distribution patterns, and resulted in the delineation of 5 target areas, described below. 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, with the shallow sampling considered to approximately represent sedimentation occurring during the past 100 years and, therefore, may be subject to anthropogenic contamination. The deep sediment sample represents sedimentation older than 100 years; therefore, this portion better reflects 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 be representative.

Proportional dot maps for lithium and cesium are plotted over general bedrock geology. “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 trace element concentrations.

Regional ice movement indicates a southwest movement, fanning out to the west and south, based on glacial striae and features such as drumlins and eskers (Zoltai 1966), indicating that the observed anomalies are most likely not derived from the pegmatite fields located north of Lake Nipigon, or from the Georgia Lake pegmatite field to the south; further supporting the idea that undiscovered lithium potential lies within the Greenstone area. All 5 target areas display varying degrees of outcrop and possible outcrop based on satellite imagery; due to the scale necessary to observe these features, the imagery has not been included in this publication.

Target area 1 consists of Frank Lake and a series of smaller lakes to the east (Figures 3A and 3B, found after the "References" section). Stott et al. (2002), reveals several felsic intrusions or multiple phases. The "core" was mapped as a medium- to fine-grained locally biotitic and quartz porphyritic granodiorite to tonalite, which is wrapped by an unknown age Archean diorite to quartz diorite gneiss along the northern margin, while along the southern edge is a fine- to medium-grained, foliated biotite-bearing tonalite to granodiorite of the Humbolt assemblage (Stott et al. 2002). These bodies are bound to the northeast and southeast by the Robinson and Jackson plutons; all of which are within the southern margin of the larger Lamaune batholith (McCrank, Misiura and Brown et al. 1981). The easternmost portion is bound by the Humbolt and Elmhirst–Rickaby assemblages, with local gabbroic intrusions (Stott et al. 2002).

Target area 2 is located near Humbolt Bay of Lake Nipigon (Figures 4A and 4B, found after the "References" section). The only anomalies that appear are seen in the shallow sediment sampling in the bay itself, otherwise both shallow and deep anomalies are observed in the small lake to the southeast of the area. This area is located near the northern contact of the North Wind Pluton and rocks of the Humbolt and Elmhirst–Rickaby assemblages and the Lamaune batholith.

Target area 3 consists of North Wind Lake, within the North Wind Lake pluton (Figures 5A and 5B, found after the "References" section). The pluton is mapped as a quartz porphyritic biotite granodiorite to tonalite with numerous north-northeast–trending diabase dikes and minor northwest-trending diabase dikes (Stott et al. 2002). Previous work by Kresz and Zayachivsky (1989) showed numerous granitic dikes extending into the supracrustal lithologies in Meader and Pifner townships, and in the northern part of Barbara Township. The pluton's contact is marked by numerous granitic dikes in the metavolcanic rocks and xenoliths in the intrusion. Narrow (generally less than 0.5 m wide) and randomly oriented quartz-feldspar pegmatite and aplite dikes are common along the contact especially along Tyrol Lake and at Vint Bay on Lake Nipigon. Kresz and Zayachivsky (1989) have suggested the presence of a northwest to southwest compositional zonation in the pluton. The pluton is surrounded by rocks of the Humbolt assemblage (<2713 Ma) and the Elmhirst–Rickaby assemblage (2740 Ma) (Stott et al. 2002).

Target area 4 is centred over Burrows Lake (Figures 6A and 6B, found after the "References" section) within the Onaman pluton (Stott et al. 2002); a medium- to fine-grained locally biotitic and quartz porphyritic granodiorite to tonalite, and a fine- to medium-grained, foliated to banded tonalite to granodiorite gneiss with late granite dikes and amphibolite inclusions which may be related to a part of the Nakina tonalite gneiss (Stott et al. 2002). The southern margin abuts the Onaman assemblage (2270–2780 Ma), the Quetico assemblage (2680 Ma) and the Elmhirst–Rickaby assemblage (Stott et al. 2002).

Target area 5 is located to the east of Long Lake and west of McKay Lake and south of the past-producing Theresa gold mine (Figures 7A and 7B, found after the "References" section). This area is situated primarily within the metasedimentary and associated paragneiss and migmatite rocks of the Quetico Subprovince and the southern margin of the Eastern Wabigoon Subprovince (Beardmore–Geraldton belt) (Johns, McIlraith and Stott 2003). South of the target area are 2 large granite to granodiorite plutons; one is mapped as a peraluminous S-type granite (Johns, McIlraith and Stott 2003). The area lies to the northeast of the Georgia Lake pegmatite field.

Grassroots exploration of the 5 target areas should include both the determination of and examination of any regional zoning of fertile granites and pegmatite dikes. Followed by bulk whole-rock compositions and bulk potassium feldspar and muscovite compositions to determine the degree of fractionation of the granite and pegmatite, and identifying the presence of tantalum minerals, as well as sampling of metasomatized host rocks (Selway, Breaks and Tindle 2005), to vector onto any (LCT) pegmatites.

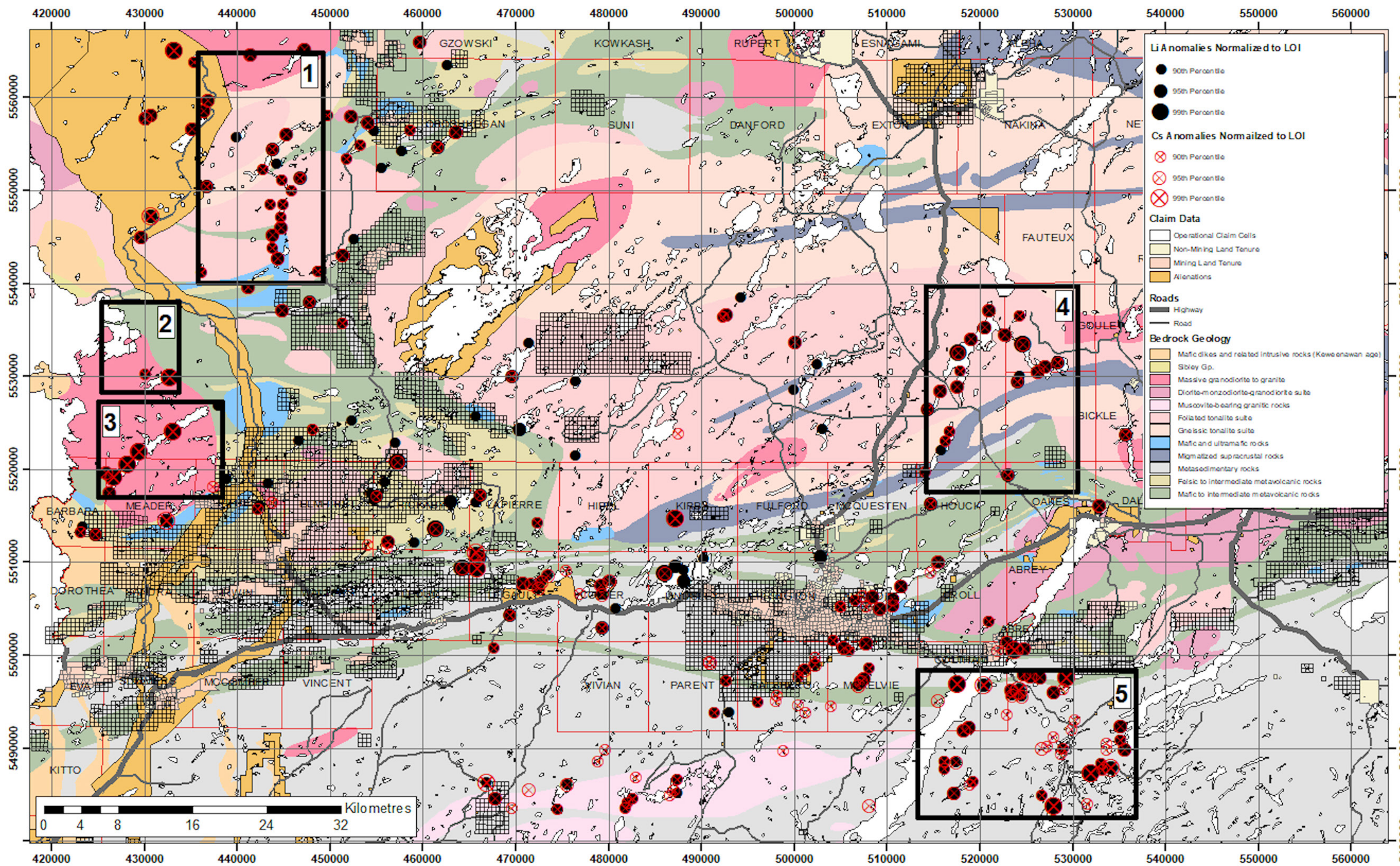

Figure 1. Target areas (1 to 5) overlain on bedrock geology with deep sediment sampling lithium and cesium anomalies. Geology data *from* Ontario Geological Survey (2011); lake sediment data *from* Handley and Dyer (2018); Universal Transverse Mercator (UTM) co-ordinates in North American Datum (NAD83), Zone 16. Claim units current to November 16, 2018.

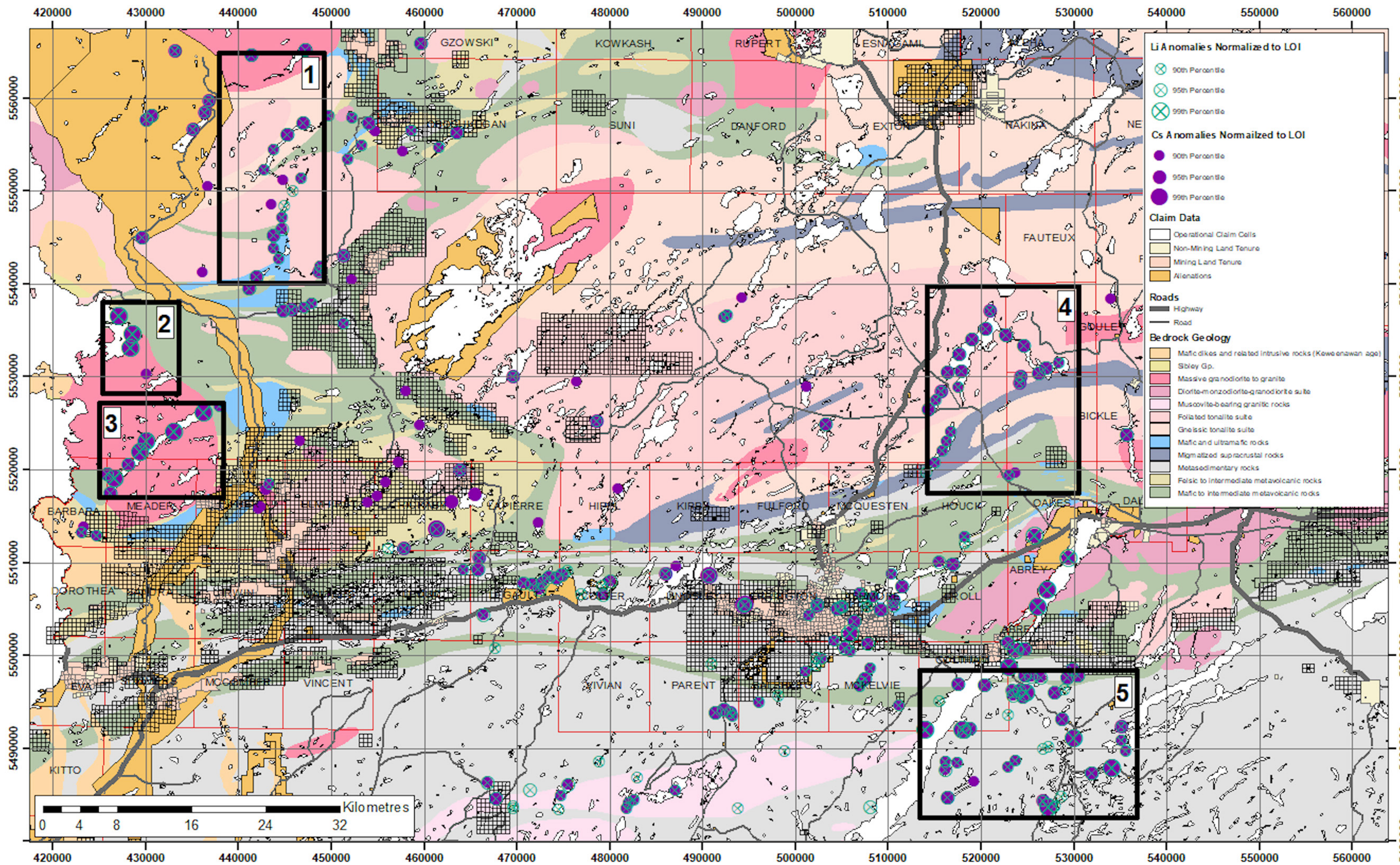

Figure 2. Target areas (1 to 5) overlain on bedrock geology with shallow sediment sampling lithium and cesium anomalies. Geology data *from* Ontario Geological Survey (2011); lake sediment data *from* Handley and Dyer (2018); Universal Transverse Mercator (UTM) co-ordinates in North American Datum (NAD83), Zone 16. Claim units current to November 16, 2018.

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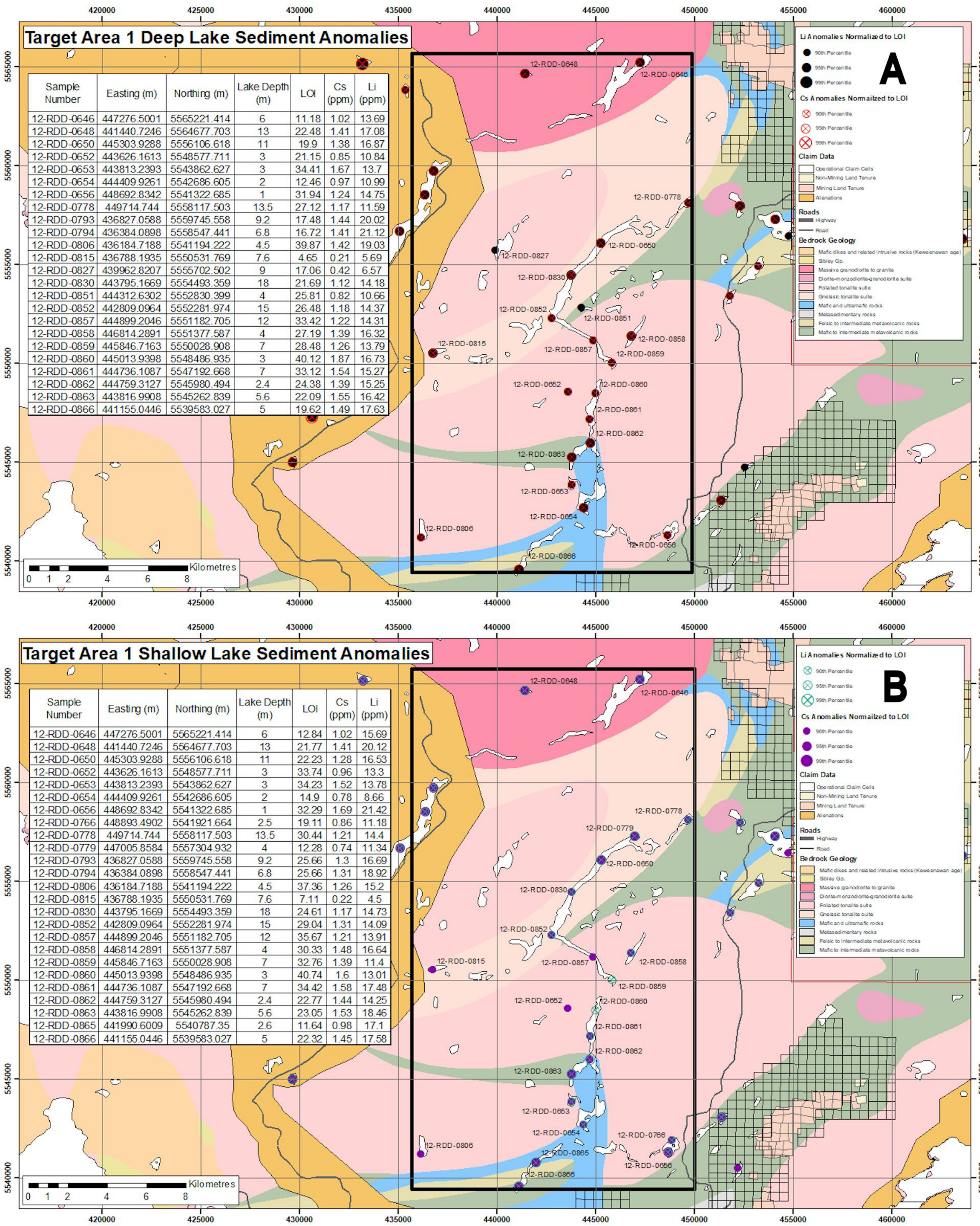


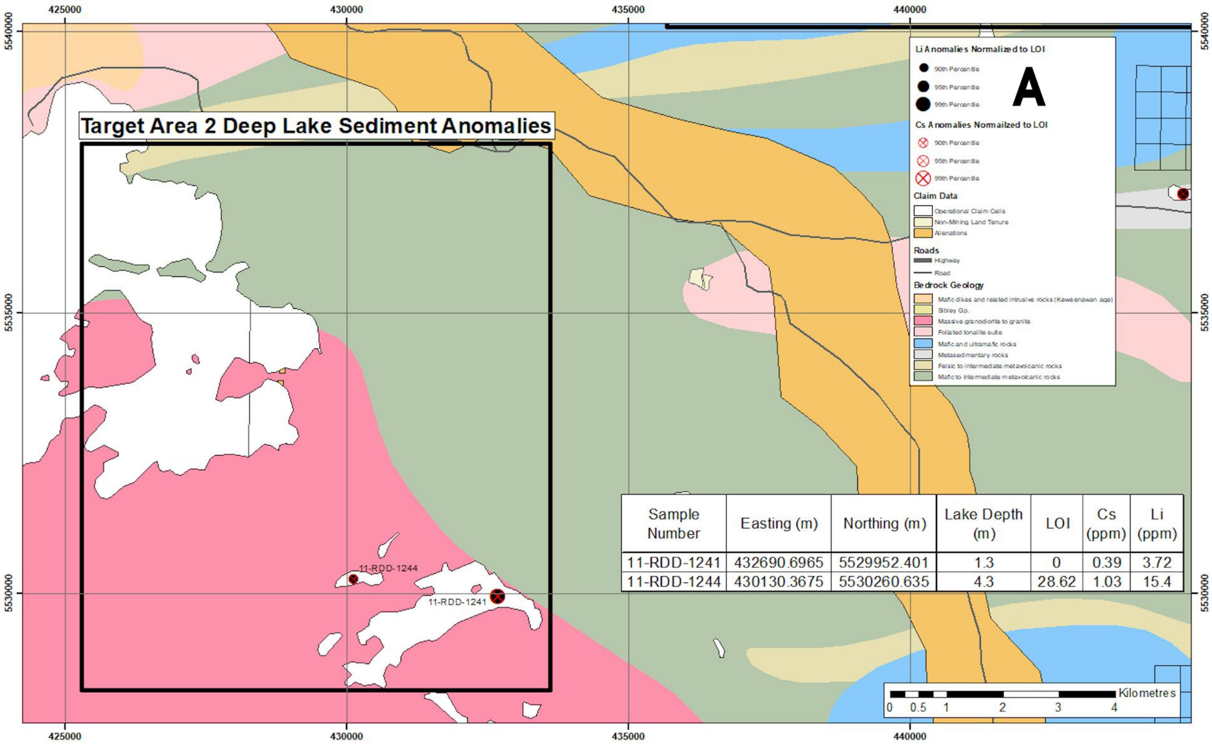
Target Area 1 Deep Lake Sediment Anomalies

Sample Number	Easting (m)	Northing (m)	Lake Depth (m)	LOI	Cs (ppm)	Li (ppm)
12-RDD-0646	447276.5001	5565221.414	6	11.18	1.02	13.69
12-RDD-0648	441440.7246	5564677.703	13	22.48	1.41	17.08
12-RDD-0650	445303.9288	5556106.618	11	19.9	1.38	16.87
12-RDD-0652	443626.1613	5548577.711	3	21.15	0.85	10.84
12-RDD-0653	443813.2393	5543862.627	3	34.41	1.67	13.7
12-RDD-0654	444409.9261	5542686.605	2	12.46	0.97	10.99
12-RDD-0656	448692.8342	5541322.685	1	31.94	1.24	14.75
12-RDD-0778	449714.744	5558117.503	13.5	27.12	1.17	11.59
12-RDD-0793	436827.0588	5559745.558	9.2	17.48	1.44	20.02
12-RDD-0794	436384.0898	5558547.441	6.8	16.72	1.41	21.12
12-RDD-0806	436184.7188	5541194.222	4.5	39.87	1.42	19.03
12-RDD-0815	436788.1935	5550531.769	7.6	4.65	0.21	5.69
12-RDD-0827	439962.8207	5555702.502	9	17.06	0.42	6.57
12-RDD-0830	443795.1669	5554493.359	18	21.69	1.12	14.18
12-RDD-0851	444312.6302	5552830.399	4	25.81	0.82	10.66
12-RDD-0852	442809.0964	5552281.974	15	26.48	1.18	14.37
12-RDD-0857	444899.2046	5551182.705	12	33.42	1.22	14.31
12-RDD-0858	446814.2891	5551377.587	4	27.19	1.39	16.32
12-RDD-0859	445846.7163	5550028.908	7	28.48	1.26	13.79
12-RDD-0860	445013.9398	5548486.935	3	40.12	1.87	16.73
12-RDD-0861	444736.1087	5547192.668	7	33.12	1.54	15.27
12-RDD-0862	444759.3127	5545980.494	2.4	24.38	1.39	15.25
12-RDD-0863	443816.9908	5545262.839	5.6	22.09	1.55	16.42
12-RDD-0866	441155.0446	5539583.027	5	19.62	1.49	17.63

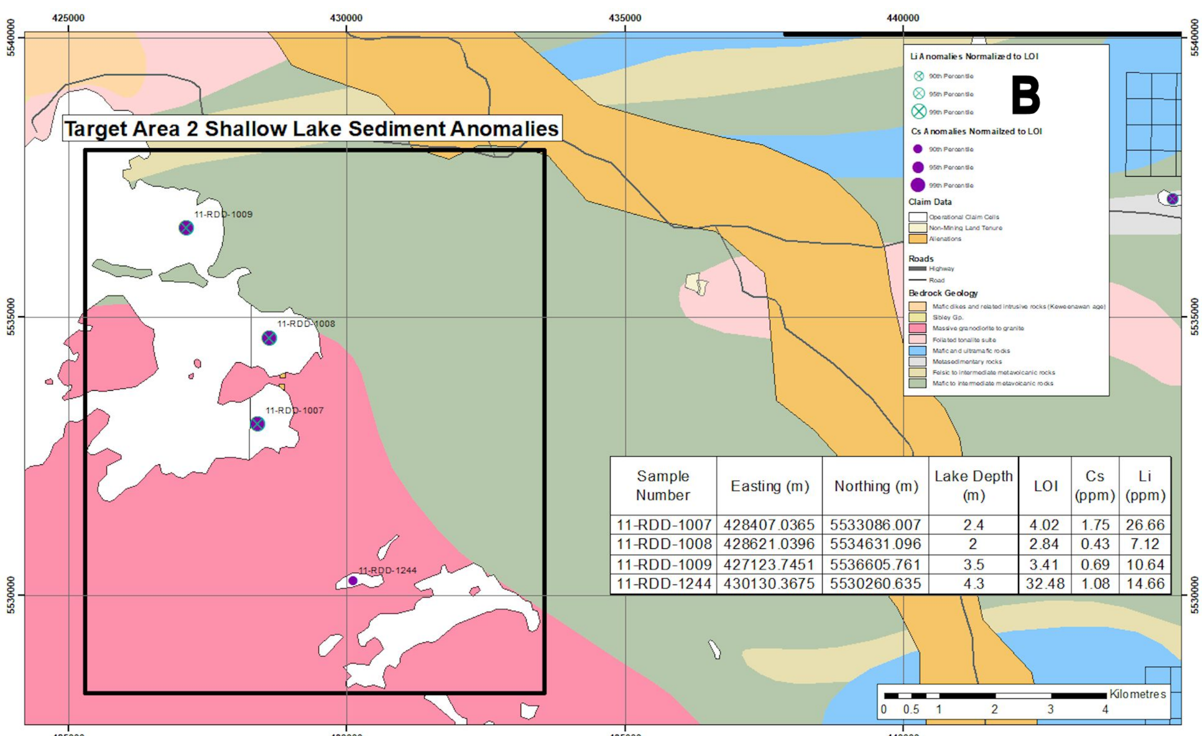
Target Area 1 Shallow Lake Sediment Anomalies

Sample Number	Easting (m)	Northing (m)	Lake Depth (m)	LOI	Cs (ppm)	Li (ppm)
12-RDD-0646	447276.5001	5565221.414	6	12.84	1.02	15.69
12-RDD-0648	441440.7246	5564677.703	13	21.77	1.41	20.12
12-RDD-0650	445303.9288	5556106.618	11	22.23	1.28	16.53
12-RDD-0652	443626.1613	5548577.711	3	33.74	0.96	13.3
12-RDD-0653	443813.2393	5543862.627	3	34.23	1.52	13.78
12-RDD-0654	444409.9261	5542686.605	2	14.9	0.78	8.66
12-RDD-0656	448692.8342	5541322.685	1	32.29	1.69	21.42
12-RDD-0766	448893.4902	5541921.664	2.5	19.11	0.86	11.18
12-RDD-0778	449714.744	5558117.503	13.5	30.44	1.21	14.4
12-RDD-0779	447005.8584	5557304.932	4	12.28	0.74	11.34
12-RDD-0793	436827.0588	5559745.558	9.2	25.66	1.3	16.69
12-RDD-0794	436384.0898	5558547.441	6.8	25.66	1.31	18.92
12-RDD-0806	436184.7188	5541194.222	4.5	37.36	1.26	15.2
12-RDD-0815	436788.1935	5550531.769	7.6	7.11	0.22	4.5
12-RDD-0830	443795.1669	5554493.359	18	24.61	1.17	14.73
12-RDD-0852	442809.0964	5552281.974	15	29.04	1.31	14.09
12-RDD-0857	444899.2046	5551182.705	12	35.67	1.21	13.91
12-RDD-0858	446814.2891	5551377.587	4	30.33	1.48	16.64
12-RDD-0859	445846.7163	5550028.908	7	32.76	1.39	11.4
12-RDD-0860	445013.9398	5548486.935	3	40.74	1.6	13.01
12-RDD-0861	444736.1087	5547192.668	7	34.42	1.58	17.48
12-RDD-0862	444759.3127	5545980.494	2.4	22.77	1.44	14.25
12-RDD-0863	443816.9908	5545262.839	5.6	23.05	1.53	18.46
12-RDD-0865	441990.6009	5540787.35	2.6	11.64	0.98	17.1
12-RDD-0866	441155.0446	5539583.027	5	22.32	1.45	17.58

Figure 3. Target area 1 overlain on bedrock geology. **A)** Deep and **B)** shallow sediment sampling lithium and cesium anomalies. Geology data *from* Ontario Geological Survey (2011); 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 November 16, 2018.

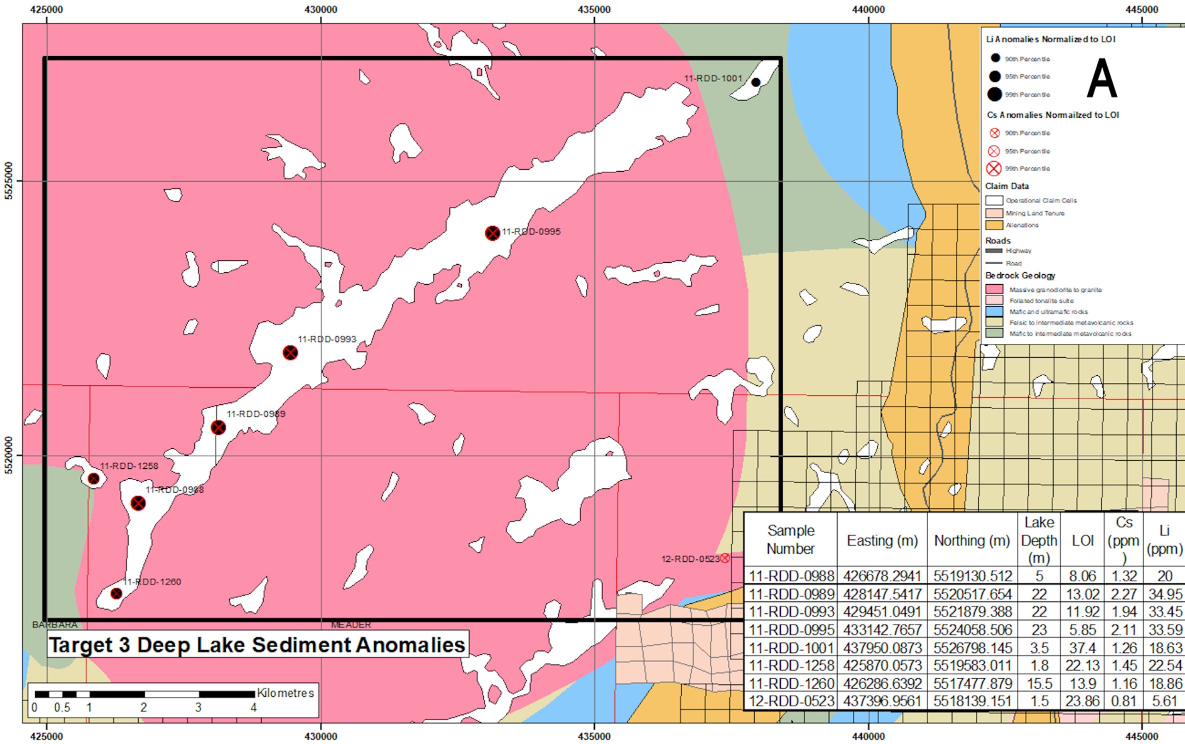


Sample Number	Easting (m)	Northing (m)	Lake Depth (m)	LOI	Cs (ppm)	Li (ppm)
11-RDD-1241	432690.6965	5529952.401	1.3	0	0.39	3.72
11-RDD-1244	430130.3675	5530260.635	4.3	28.62	1.03	15.4

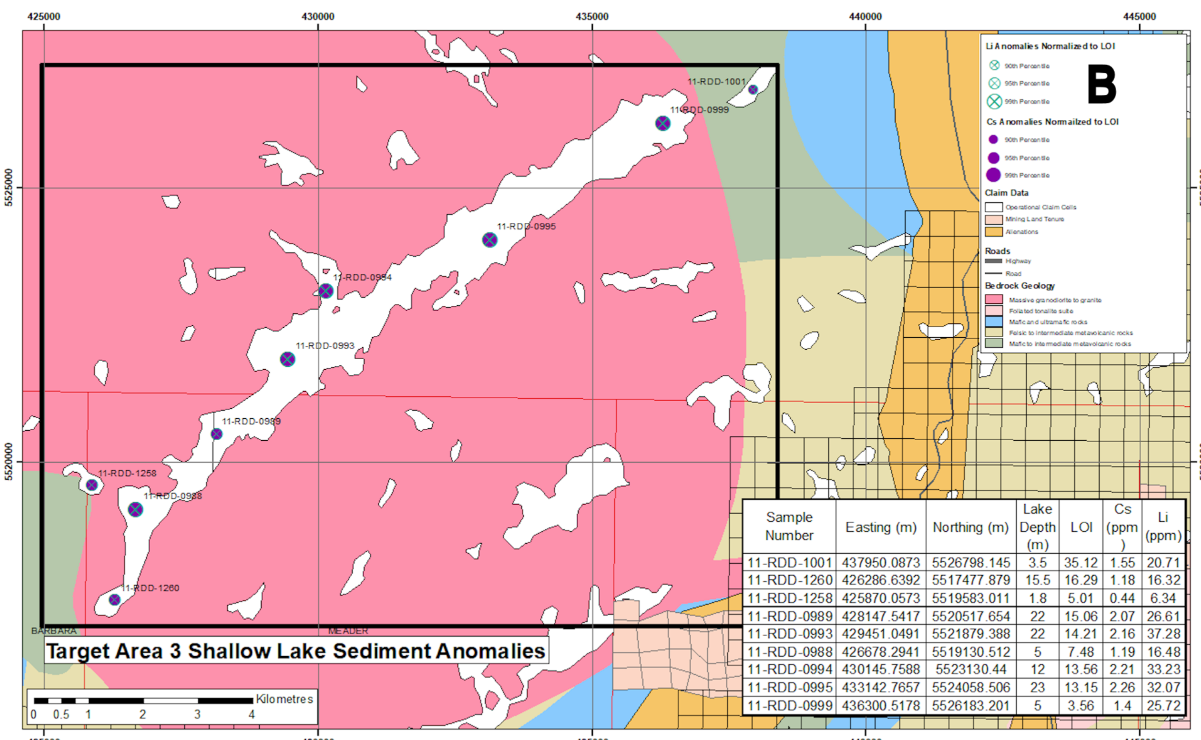


Sample Number	Easting (m)	Northing (m)	Lake Depth (m)	LOI	Cs (ppm)	Li (ppm)
11-RDD-1007	428407.0365	5533086.007	2.4	4.02	1.75	26.66
11-RDD-1008	428621.0396	5534631.096	2	2.84	0.43	7.12
11-RDD-1009	427123.7451	5536605.761	3.5	3.41	0.69	10.64
11-RDD-1244	430130.3675	5530260.635	4.3	32.48	1.08	14.66

Figure 4. Target area 2 overlain on bedrock geology. **A)** Deep and **B)** shallow sediment sampling lithium and cesium anomalies. Geology data *from* Ontario Geological Survey (2011); 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 November 16, 2018.

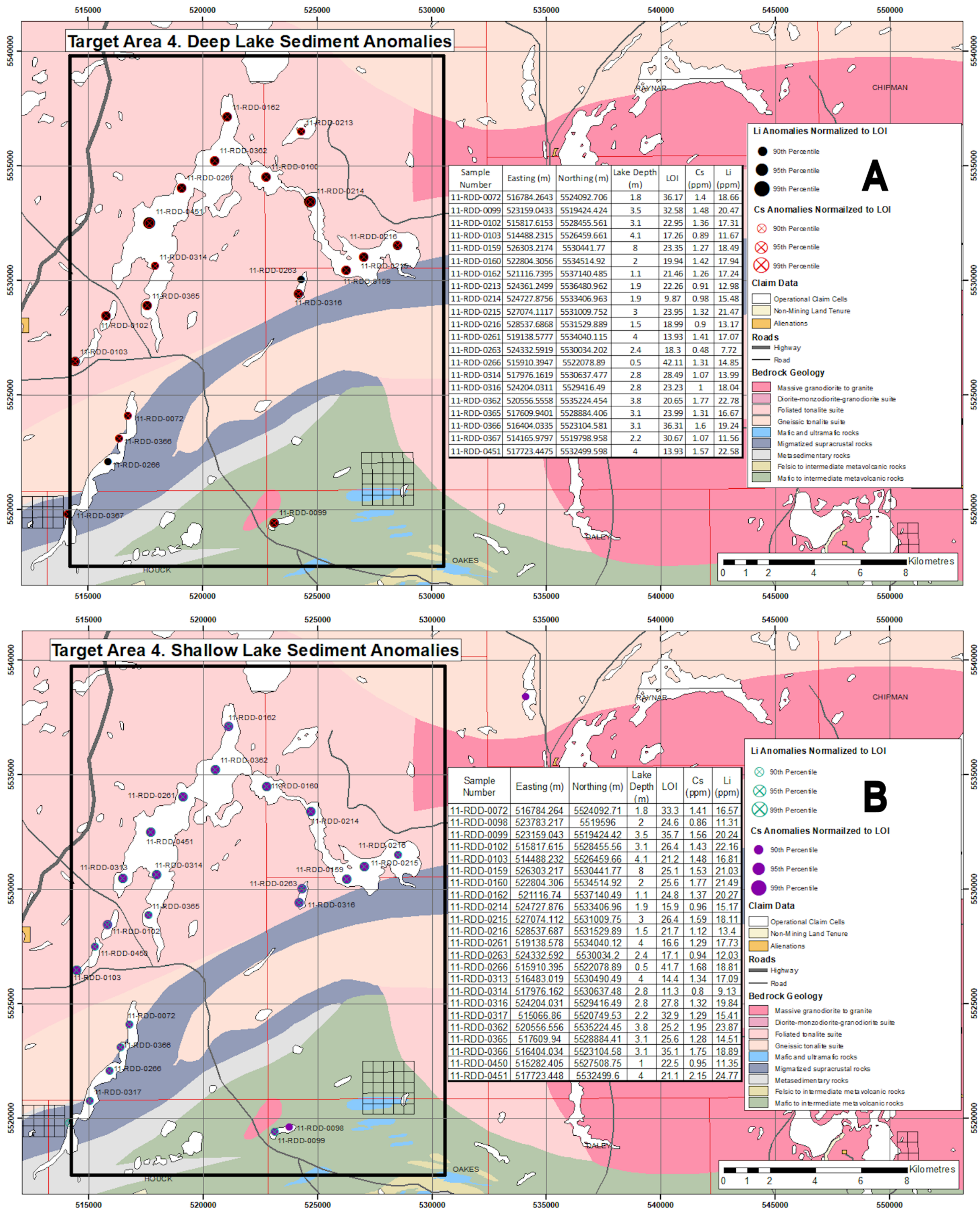


Sample Number	Easting (m)	Northing (m)	Lake Depth (m)	LOI	Cs (ppm)	Li (ppm)
11-RDD-0988	426678.2941	5519130.512	5	8.06	1.32	20
11-RDD-0989	428147.5417	5520517.654	22	13.02	2.27	34.95
11-RDD-0993	429451.0491	5521879.388	22	11.92	1.94	33.45
11-RDD-0995	433142.7657	5524058.506	23	5.85	2.11	33.59
11-RDD-1001	437950.0873	5526798.145	3.5	37.4	1.26	18.63
11-RDD-1258	425870.0573	5519583.011	1.8	22.13	1.45	22.54
11-RDD-1260	426286.6392	5517477.879	15.5	13.9	1.16	18.86
12-RDD-0523	437396.9561	5518139.151	1.5	23.86	0.81	5.61



Sample Number	Easting (m)	Northing (m)	Lake Depth (m)	LOI	Cs (ppm)	Li (ppm)
11-RDD-1001	437950.0873	5526798.145	3.5	35.12	1.55	20.71
11-RDD-1260	426286.6392	5517477.879	15.5	16.29	1.18	16.32
11-RDD-1258	425870.0573	5519583.011	1.8	5.01	0.44	6.34
11-RDD-0989	428147.5417	5520517.654	22	15.06	2.07	26.61
11-RDD-0993	429451.0491	5521879.388	22	14.21	2.16	37.28
11-RDD-0988	426678.2941	5519130.512	5	7.48	1.19	16.48
11-RDD-0994	430145.7588	5523130.44	12	13.56	2.21	33.23
11-RDD-0995	433142.7657	5524058.506	23	13.15	2.26	32.07
11-RDD-0999	436300.5178	5526183.201	5	3.56	1.4	25.72

Figure 5. Target area 3 overlain on bedrock geology. **A)** Deep and **B)** shallow sediment sampling lithium and cesium anomalies. Geology data *from* Ontario Geological Survey (2011); 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 November 16, 2018.



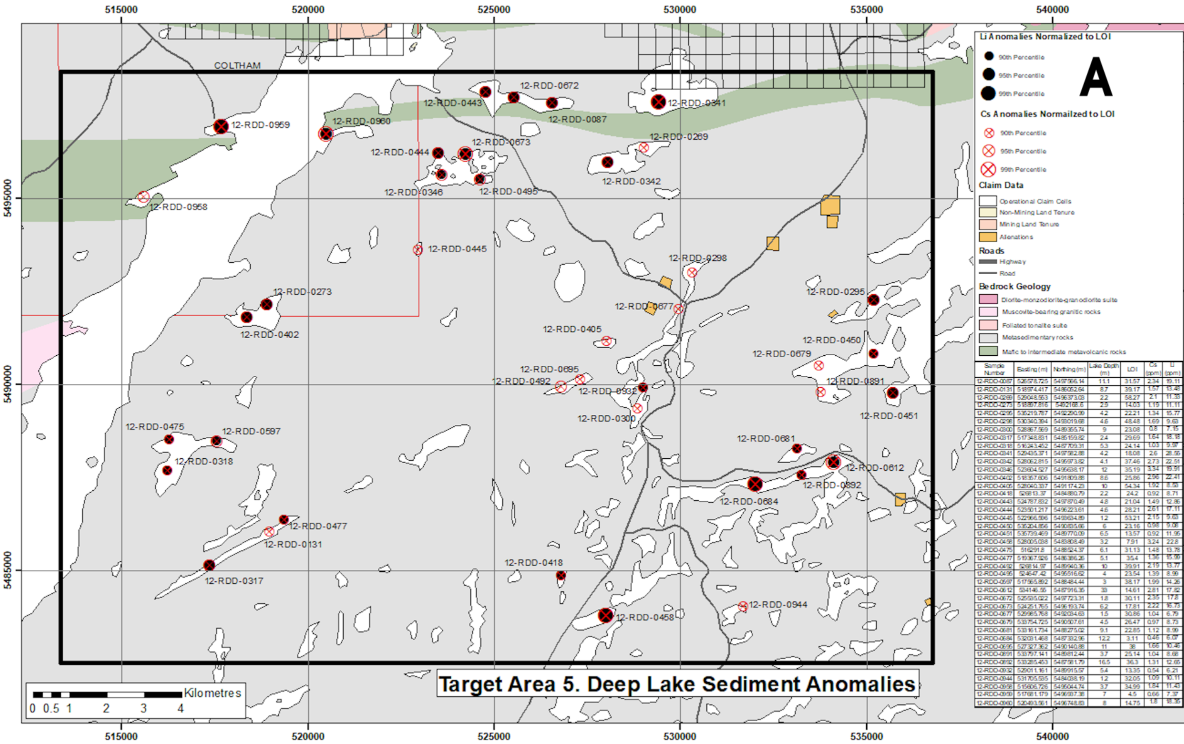
A) Deep lake sediment anomalies

Sample Number	Easting (m)	Northing (m)	Lake Depth (m)	LOI	Cs (ppm)	Li (ppm)
11-RDD-0072	516784.2643	5524092.706	1.8	36.17	1.4	18.66
11-RDD-0099	523159.0433	5519424.424	3.5	32.58	1.48	20.47
11-RDD-0102	515817.6153	5528455.561	3.1	22.95	1.36	17.31
11-RDD-0103	514488.2315	5526459.661	4.1	17.26	0.89	11.67
11-RDD-0159	526303.2174	5530441.77	8	23.35	1.27	18.49
11-RDD-0160	522804.3056	5534514.92	2	19.94	1.42	17.94
11-RDD-0162	521116.7395	5537140.485	1.1	21.46	1.26	17.24
11-RDD-0213	524361.2499	5536480.962	1.9	22.26	0.91	12.98
11-RDD-0214	524727.8756	5533406.963	1.9	9.87	0.98	15.48
11-RDD-0215	527074.1117	5531009.752	3	23.95	1.32	21.47
11-RDD-0216	528537.6868	5531529.889	1.5	18.99	0.9	13.17
11-RDD-0261	519138.5777	5534040.115	4	13.93	1.41	17.07
11-RDD-0263	524332.5919	5530034.202	2.4	18.3	0.48	7.72
11-RDD-0266	515910.3947	5522078.89	0.5	42.11	1.31	14.85
11-RDD-0314	517976.1619	5530637.477	2.8	28.49	1.07	13.99
11-RDD-0316	524204.0311	5529416.49	2.8	23.23	1	18.04
11-RDD-0362	520556.5558	5535224.454	3.8	20.65	1.77	22.78
11-RDD-0365	517609.9401	5528884.406	3.1	23.99	1.31	16.67
11-RDD-0366	516404.0335	5523104.581	3.1	36.31	1.6	19.24
11-RDD-0367	514165.9797	5519798.958	2.2	30.67	1.07	11.56
11-RDD-0451	517723.4475	5532499.598	4	13.93	1.57	22.58

B) Shallow lake sediment anomalies

Sample Number	Easting (m)	Northing (m)	Lake Depth (m)	LOI	Cs (ppm)	Li (ppm)
11-RDD-0072	516784.264	5524092.71	1.8	33.3	1.41	16.57
11-RDD-0098	523783.217	5519596	2	24.6	0.86	11.31
11-RDD-0099	523159.043	5519424.42	3.5	35.7	1.56	20.24
11-RDD-0102	515817.615	5528455.56	3.1	26.4	1.43	22.16
11-RDD-0103	514488.232	5526459.66	4.1	21.2	1.48	16.81
11-RDD-0159	526303.217	5530441.77	8	25.1	1.53	21.03
11-RDD-0160	522804.306	5534514.92	2	25.6	1.77	21.49
11-RDD-0162	521116.74	5537140.49	1.1	24.8	1.37	20.27
11-RDD-0214	524727.876	5533406.96	1.9	15.9	0.96	15.17
11-RDD-0215	527074.112	5531009.75	3	26.4	1.59	18.11
11-RDD-0216	528537.687	5531529.89	1.5	21.7	1.12	13.4
11-RDD-0261	519138.578	5534040.12	4	16.6	1.29	17.73
11-RDD-0263	524332.592	5530034.2	2.4	17.1	0.94	12.03
11-RDD-0266	515910.395	5522078.89	0.5	41.7	1.68	18.81
11-RDD-0313	516483.019	5530490.49	4	14.4	1.34	17.09
11-RDD-0314	517976.162	5530637.48	2.8	11.3	0.8	9.13
11-RDD-0316	524204.031	5529416.49	2.8	27.8	1.32	19.84
11-RDD-0317	515066.86	5520749.53	2.2	32.9	1.29	15.41
11-RDD-0362	520556.556	5535224.45	3.8	25.2	1.95	23.87
11-RDD-0365	517609.94	5528884.41	3.1	25.6	1.28	14.51
11-RDD-0366	516404.034	5523104.58	3.1	35.1	1.75	18.89
11-RDD-0450	515282.405	5527508.75	1	22.5	0.95	11.35
11-RDD-0451	517723.448	5532499.6	4	21.1	2.15	24.77

Figure 6. Target area 4 overlain on bedrock geology. **A)** Deep and **B)** shallow sediment sampling lithium and cesium anomalies. Geology data *from* Ontario Geological Survey (2011); 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 of November 16, 2018.



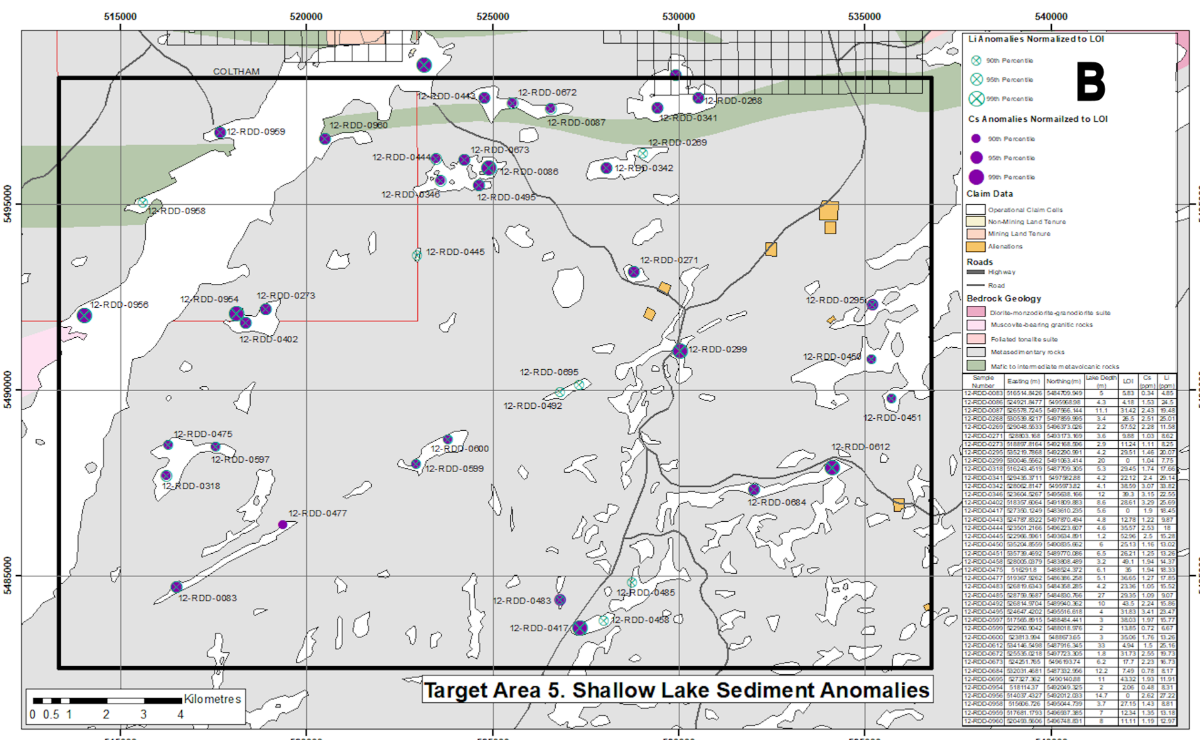


Figure 7. Target area 5 overlain on bedrock geology. **A)** Deep and **B)** shallow sediment sampling lithium and cesium anomalies. Geology data *from* Ontario Geological Survey (2011); lake sediment data *from* Handley and Dyer (2018); Universal Transverse Mercator (UTM) co-ordinates in North American Datum (NAD83), Zone 16. Claim units current to November 16, 2018.

Sault Ste. Marie District—Areas Open for Uranium Exploration

HIGHLIGHTS

- **34 uranium occurrences and 1 copper-uranium prospect are open for staking in the Sault Ste. Marie District**
- **Many of the unstaked occurrences lie in the area covered by the Ramsey–Algoma airborne geophysical survey flown by the Ontario Geological Survey in 2018**

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Summary

Analysis of the Mineral Deposit Inventory (MDI) database for the Sault Ste. Marie Resident Geologist District identified 35 areas with uranium occurrences and prospects that are open for staking. Uranium prices are forecast to increase by 75% by 2022 (Piggott 2018). The number of unstaked occurrences in the District, particularly in the Elliot Lake area, indicates that substantial exploration potential still exists. The Elliot Lake mining camp produced approximately 350 million pounds of U_3O_8 between 1954 and 1996 from 12 mines (Bennett, Hailstone and Fremlin 1997). Recent airborne magnetic and radiometric surveys flown by the Ontario Geological Survey (Ramsey–Algoma Airborne Geophysical Survey, in progress) will provide new data to support exploration of both historic and possibly new occurrences.

Methodology

Unstaked uranium occurrences were identified first by selecting all mineral occurrences in the MDI database (Ontario Geological Survey 2018) in the District that did not fall within the bounds of patented or leased claims (except for surface rights only), withdrawn areas, and areas that are currently staked. The resulting data was queried for occurrences that have uranium listed as either a primary or secondary commodity. Discretionary mineral occurrences were omitted from the list. The analysis identified 34 unstaked uranium mineral occurrences and 1 prospect in the District (information current to October 23, 2018). The location of the occurrences is shown in Figure 1 and the names of the occurrences along with their MDI number are listed in Table 1. Many of the occurrences open for staking are located to the west and northwest of the Town of Elliot Lake. Bolger Township has 4 occurrences open for staking, the most of any township; and Beange, Gunterman, Timmermans, and Raimbault each have 3 unstaked occurrences.

Cautionary Statement

The occurrences presented on these maps were open for staking at the time of writing (October 23, 2018). The co-ordinates of occurrences in the MDI database used to generate these maps might be offset from their actual location on the ground. It is recommended that users of this volume "2018–2019 Recommendations for Exploration" consult original documents and RGP staff to verify the location of any occurrences.

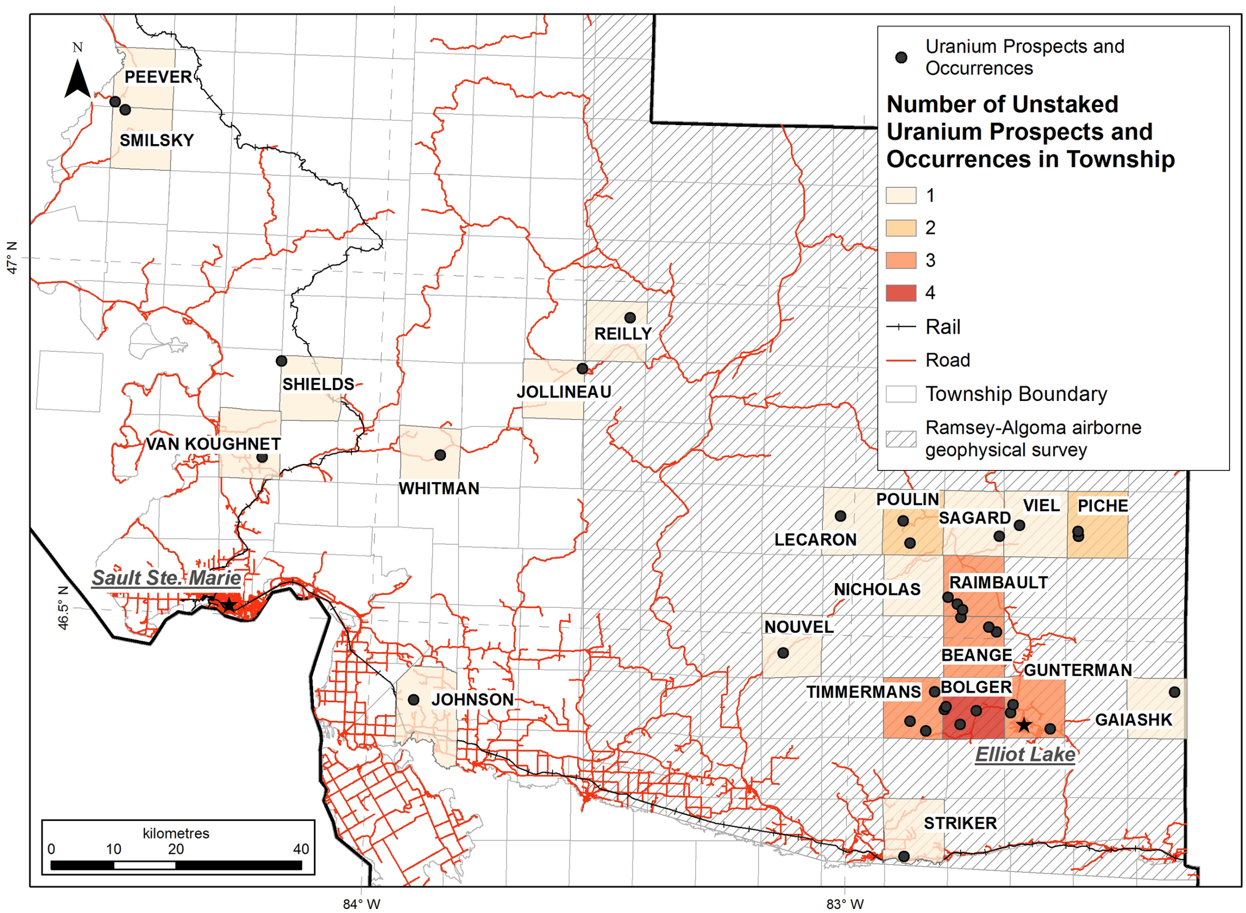

Figure 1. Areas of unstaked uranium occurrences and prospects in the Sault Ste. Marie District (current to October 23, 2018).

Table 1. Summary information for the 34 uranium occurrences and 1 prospect open for staking in the Sault Ste. Marie District as of October 23rd, 2018.

Occurrence Name	MDI Number	Deposit Status	Primary Commodity (Secondary)	Township
Consolidated Callinan	MDI41J10SW00057	Occurrence	Uranium	Beange
Candore	MDI41J10SE00026	Occurrence	Uranium	Beange
Span-North	MDI41J10SE00028	Occurrence	Uranium	Beange
Nordic Group West	MDI41J07NW00056	Occurrence	Uranium	Bolger
Gui-Por	MDI41J07NW00054	Occurrence	Uranium (Thorium)	Bolger
Peerless	MDI41J07NW00057	Occurrence	Uranium	Bolger
Moon Lake	MDI41J07NW00055	Occurrence	Uranium (Thorium)	Bolger
Canuc	MDI41J08NW00070	Occurrence	Uranium	Gaiashk

Occurrence Name	MDI Number	Deposit Status	Primary Commodity (Secondary)	Township
Kamis	MDI41J07NE00112	Occurrence	Uranium	Gunterman
North American Nuclear	MDI41J07NE00086	Occurrence	Uranium	Gunterman
Genex	MDI41J07NE00082	Occurrence	Uranium	Gunterman
Desbarats Lake	MDI41J05NW00040	Occurrence	Uranium	Johnson
Gardiner, M.C.	MDI41J13NE00004	Occurrence	Uranium	Jollineau
Kirkpatrick Lake	MDI41J11NE00012	Occurrence	Uranium	Lecaron
Hecla Ddh 15	MDI41J10SW00053	Occurrence	Uranium	Nicholas
Sheba	MDI41J06NE00047	Prospect	Copper (Uranium)	Nouvel
Ranwick	MDI41N02NE00002	Occurrence	Uranium	Peever
Consolidated Golden	MDI41J10NE00030	Occurrence	Uranium, Thorium	Piche
Inspiration	MDI41J10NE00025	Occurrence	Uranium	Piche
Cobalt Consolidated	MDI41J10NW00014	Occurrence	Uranium	Poulin
Iron Lake	MDI41J10NW00013	Occurrence	Uranium	Poulin
Gods Lake	MDI41J10SW00054	Occurrence	Uranium	Raimbault
Boymar	MDI41J10SW00055	Occurrence	Uranium	Raimbault
Zenmac	MDI41J10SW00056	Occurrence	Uranium	Raimbault
Ranger Lake	MDI41J14NW00012	Occurrence	Uranium	Reilly
Grey Trout-Blue Sky	MDI41J10NE00024	Occurrence	Thorium (Uranium)	Sagard
Wolfe Lake	MDI41K16SE00046	Occurrence	Copper (Uranium)	Shields
Labine-Mccarthy	MDI41N02NE00004	Occurrence	Uranium	Smilsky
Cyr Property	MDI41J02NW00016	Occurrence	Uranium	Striker
Pistol Lake	MDI41J07SW00021	Occurrence	Uranium	Timmermans
Fort Norman	MDI41J07NW00046	Occurrence	Uranium	Timmermans
Dominion	MDI41J07NW00043	Occurrence	Uranium	Timmermans
Wj Richards	MDI41K09NW00016	Occurrence	Uranium (Thorium)	Van Koughnet
Gaitwin	MDI41J10NE00026	Occurrence	Uranium	Viel
Crestland	MDI41J12NW00018	Occurrence	Uranium	Whitman

References

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Piggott, M. 2018. Consensus price forecasts—Platinum and palladium switch, cobalt cools; presentation by S&P Global Market Intelligence, November 6, 2018.

HIGHLIGHTS

- **Magnetic anomalies and conductors in Lunkie Township present prospective targets for volcanogenic massive sulphide deposits**
- **Many conductors, including one 1.5 km long, have revealed pyrrhotite, pyrite, chalcopyrite, magnetite and graphite through trenching, although few details relating to the trenching program were recorded**

VMS Targets in the Lunkie Township and the Batchawana Greenstone Belt

Introduction

Lunkie Township is situated in the eastern portion of the Batchawana greenstone belt and has potential for hosting volcanogenic massive sulphide (VMS) deposits. Past exploration work in the area and field work carried out by Resident Geologist staff in 2018 identified sulphide mineralization in Lunkie Township, including sphalerite and sulphide iron formation, which warrants follow-up work. Numerous geophysical anomalies potentially associated with sulphide mineralization also warrant additional exploration attention.

Discussion

Geological mapping and lithogeochemcial sampling of the Batchawana greenstone belt, including Lunkie Township, was carried out in the late 1970s and early 1980s by Grunsky (Grunsky 1980, 1991). The geology of Lunkie Township consists primarily of an overturned sequence of felsic to intermediate metavolcanic rocks which are cut by late Precambrian diabase dikes. The Goulais River Fault runs northeast-southwest through the north part of the township. Grunsky (1980) describes the base metal occurrences in Lunkie Township as either banded sulphide iron formation or as exhalative lenses interbedded with metavolcanic rocks. Most of the sulphide iron formation observed by Grunsky (1980) is less than 2 m thick and has not been traced more than a few hundred metres along strike. Diamond drilling carried out by Noranda Exploration Co. in the southern half of Lunkie Township (Calhoun 1986) intersected 2 intervals off massive sulphides consisting of pyrite, pyrrhotite, with minor chalcopyrite; no assays were reported.

HBOG Mining Limited (a subsidiary of Hudson's Bay Oil and Gas Company Limited) carried out magnetic and electromagnetic surveys over the area and identified 39 conductors in Lunkie Township. Four of these conductors were drilled, 24 were trenched, and 4 remain untested. Fourteen of the conductors were identified as graphite alone, while sulphides or oxides were identified at 21 conductors which included pyrrhotite, pyrite, chalcopyrite or magnetite. No known assay data is available for the many conductors that were only trenched, making them targets for re-examination using modern methods. The conductors along with associated minerals are displayed in Figure 1.

Review of the conductors recognized by HBOG Mining Limited (Geisbrecht 1977) and total magnetic field imagery from a geophysical survey in the area (Ontario Geological Survey 2003) identified 3 currently unstaked areas of interest warranting additional follow-up work. The 3 areas are labeled in Figure 1 and described as follows.

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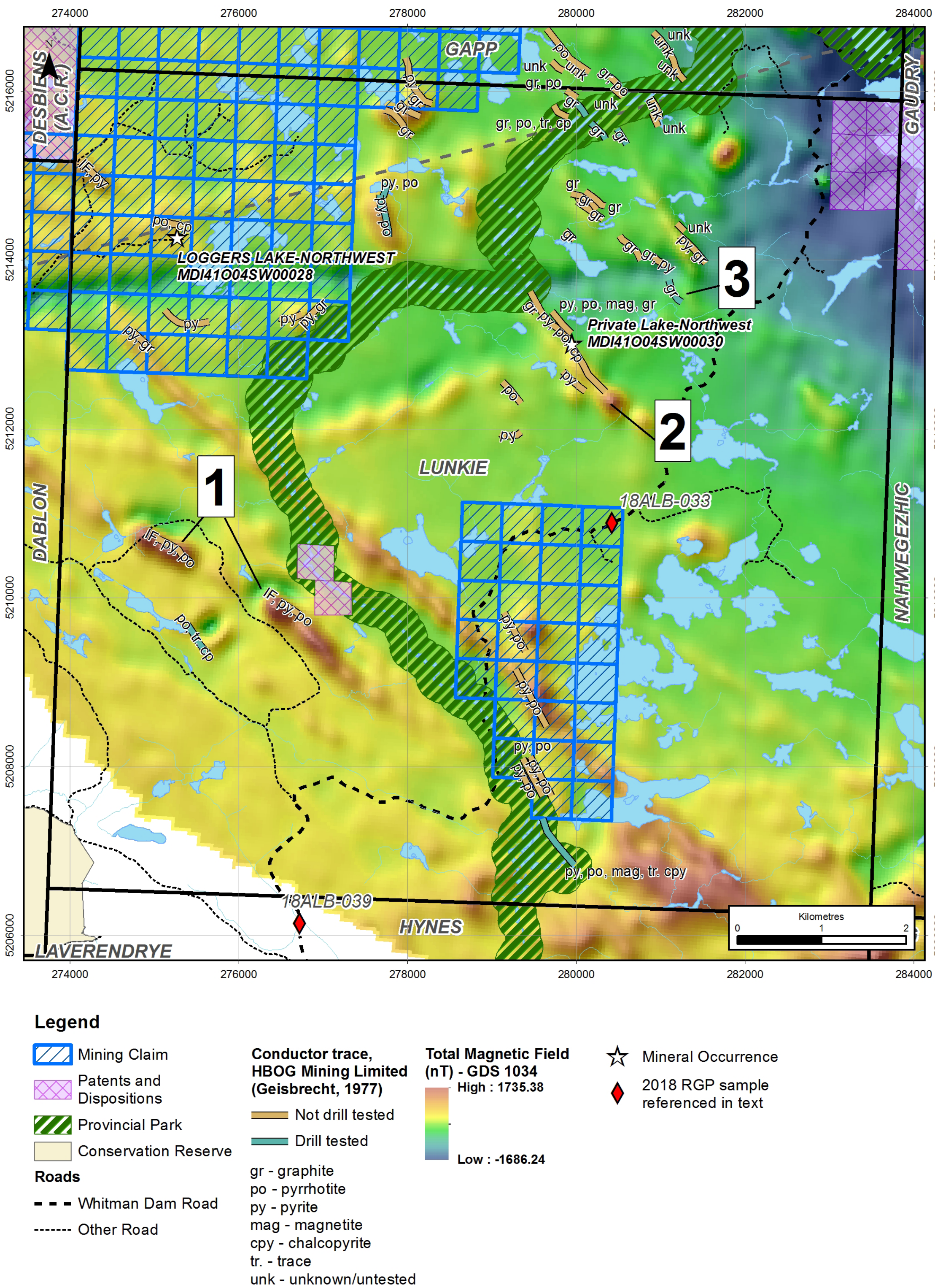
1. Two conductors coincident with magnetic highs were trenched by HBOG Mining Limited in 1976. These conductors were identified to be in association with iron formation, pyrrhotite, and pyrite. No assays are known for the easternmost conductor. Two samples were collected from the vicinity of the western conductor by Anconia Resources which returned elevated bismuth in one sample (125 ppm Bi, sample 5154486; Archibald 2011).
2. Series of 4 conductors identified by HBOG Mining Limited in 1976. The conductors were trenched and pyrite, pyrrhotite, magnetite, chalcopyrite, and graphite were identified. No assays are known for these conductors. The longest conductor has a strike length of approximately 1.5 km and is associated with a magnetic high (Ontario Geological Survey 2003). This is the location of the Private Lake Northwest MDI Occurrence (MDI41O04SW00030) (Ontario Geological Survey 2018).
3. Series of graphitic conductors trending northwest-southeast. The southernmost conductor was drilled by HBOG Mining Limited, drill hole B-GR-3-76. The drill hole intersected dacite containing sphalerite in calcite stringers with assays of up to 1.87% Zn over 0.7 feet. Two other intercepts returned 0.28% Zn over 5.1 feet in dacite with 10% pyrite and pyrrhotite in regular veinlets, seams, and blebs, and 0.28% Zn over 5.95 feet in a dacite tuff. Rare chalcopyrite was also noted in the core logs, but copper was not analyzed. Noranda conducted ground magnetic and electromagnetic surveys over this area in 1990 and identified several potential targets (Chartré 1990), but no follow-up work was reported.

2018 Field Work

Sault Ste. Marie Resident Geologist Program staff visited Lunkie Township in July 2018 and collected lithogeochemical samples to investigate the mineral potential of the area. Sulphide mineralization was observed and sampled at 2 locations along the Whitman Dam Road (samples 18ALB-033 and 18ALB-039, locations shown in Figure 1). Sphalerite in quartz veining was observed in outcrop (sample 18ALB-033, Photo 1A) and a boulder containing bedded sulphides was found in Hynes Township approximately 300 m south of the border between Lunkie and Hynes townships (sample 18ALB-039, Photo 1B). Sample 18ALB-033 was assayed and contains 2.0% Zn and 82.4 ppm Cd.

The identified areas and sample locations were open for staking at the time of writing except for where sample 18ALB-033 is located (November 5, 2018). Lunkie Township is host to numerous potential targets for exploration for commodities including zinc, copper, and gold.



Legend

Figure 1. Map of the total magnetic field of the Lunkie Township area showing HBOG Mining Limited conductor traces with mineralogy, and select samples collected by Sault Ste. Marie Resident Geologist staff in 2018. Numbers 1 to 3 correspond to the unstaked areas of interest that warrant additional follow-up work.

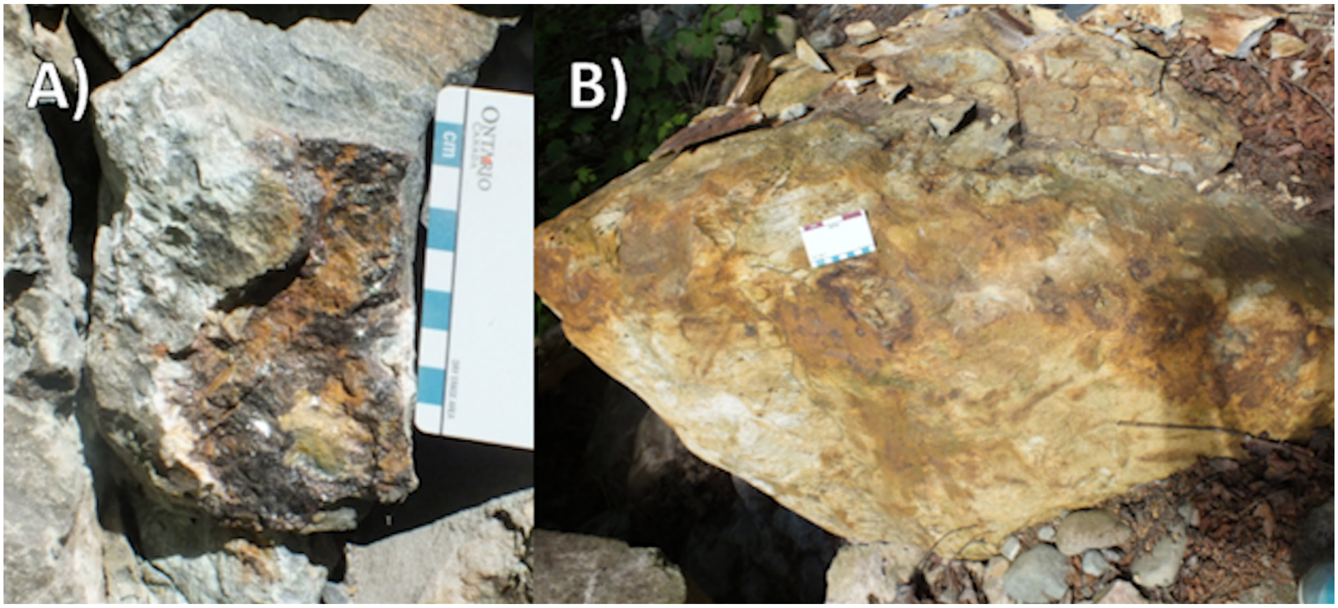


Photo 1. A) Sphalerite in sample 18ALB-033. **B)** Sulphide-rich boulder, sample 18ALB-039, 300 m south of Lunkie–Hynes township boundary. Photos by A. Bustard.

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——— 2018. Mineral Deposit Inventory; Ontario Geological Survey, Mineral Deposit Inventory, online database.

HIGHLIGHTS

- **Kamiskotia Volcanic Complex a target for volcanogenic massive sulphide deposits**
- **Altered angular rhyolite sample found along esker points to western part of the Complex**

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Volcanogenic Massive Sulphides in the Kamiskotia Volcanic Complex

The search for base metals will never cease as the global demand for them increases. The Timmins area has been a major supplier of copper and zinc because of the Kidd Creek Mine (MDI42A11NW00002). However, the mine is nearing its end of life and another deposit must be found if the area is to continue as a source of base metals. Fortunately, there are other prospective grounds for base metals in the Timmins Resident Geologist District. The author suggests that the area underlain by the Kamiskotia Volcanic Complex should be investigated further.

Geology

The Kamiskotia Volcanic Complex (KVC) extends through Carscallen, Bristol, Turnbull, Godfrey, Jamieson, Robb, Côté and Loveland townships, and is located approximately 25 km northwest of Timmins (Figure 1). Barrie (1992) defined the KVC to the west by the Kamiskotia Gabbroic Complex and a granitoid (granodiorite) body in Turnbull Township; to the north and east by a line that is parallel to stratigraphy and extends from a point 2 km east of Genex Mine to 2 km north of Kam-Kotia Mine, extending into Loveland Township and in the direction of central Bristol Township. The line represents a break between metavolcanic rocks with few electromagnetic anomalies to the west and metavolcanic–metasedimentary rocks with numerous anomalies to the east (Barlow 1988; Barrie 1992). Two units are identified as part of the KVC: felsic rocks which are composed of poorly bedded to massive pyroclastic deposits, with lesser block and ash flow material and flow–lobe complexes; and mafic volcanic rocks, comprising pillowed flows, pillow breccias hyaloclastite tuffs and breccias (Barrie 1992). Barrie (1992) observed that the units are intercalated on a scale of tens of metres and suggested that the units are coeval.

The glacial deposits overlying the KVC are mostly glaciolacustrine deposits, fine-grained to coarse-grained sand, and glaciofluvial deposits made of silty, fine-grained to pebble gravel (Richard 2000). Two eskers occur in the area: the Whitesides esker and the Kamiskotia esker (Richard 2000). Glacial movement over the KVC was in a north to south direction (Richard 2000). A 5 kg angular sample of altered rhyolite was discovered by the author along the bush road that follows the Whitesides esker in Côté Township (*see* Figure 1, red circle, Zone 17, Easting 445159 m E, Northing 5379576 m N). The rhyolite visually resembled a chert, but the major elements analysis identifies it as an altered rhyolite (Table 1). The Ishikawa alteration index (Ishikawa et al. 1976) for the sample was 91%, which suggests the rock underwent a very strong hydrothermal alteration, consistent with what is expected to occur proximal to volcanogenic massive sulphide (VMS) deposits.

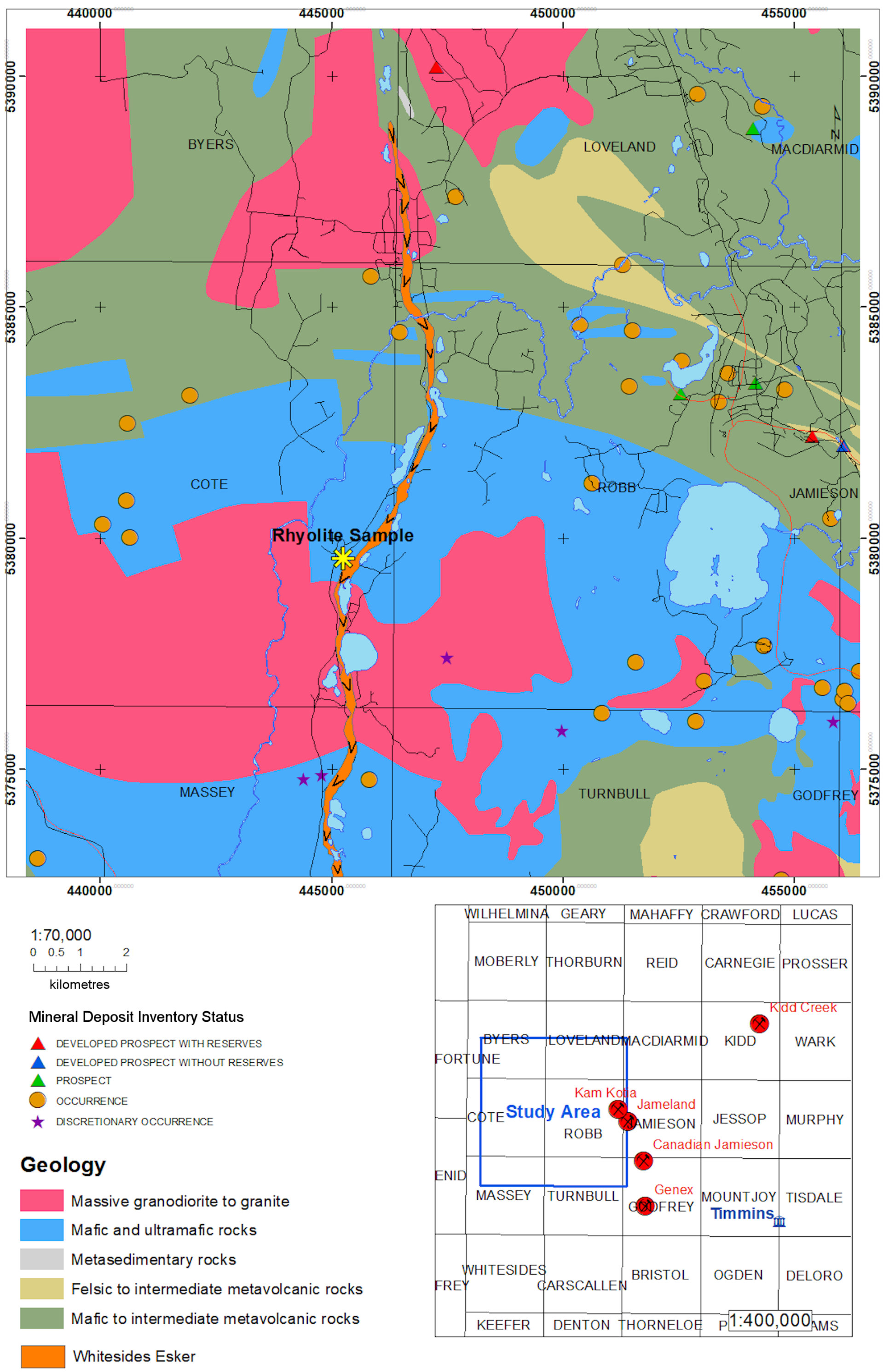

Figure 1. Location of the altered rhyolite sample (indicated by the yellow asterisk), and mineral deposits and occurrences (Ontario Geological Survey 2018). Direction of the Whitesides Esker (*from* Richard 2000) is indicated by the arrows. The inset township map shows part of the Kamiskotia Volcanic Complex area described (blue border) and mined VMS deposits (red dots). Universal Transverse Mercator (UTM) co-ordinates provided using North American Datum 1983 (NAD83) in Zone 17.

Table 1. Major element chemistry (in weight %) for the altered rhyolite sample from Côté Township.

Major Elements	Al_2O_3	BaO	CaO	Cr_2O_3	Fe_2O_3	K_2O	LOI*	MgO	MnO	Na_2O	P_2O_5	SiO_2	TiO_2	Total
Silicified Rhyolite	12.97	0.218	0.072	0.005	0.36	9.29	0.38	0.08	0.007	0.81	0.005	76.75	0.02	100.98

* *Total loss on ignition at 1000°C*

Known deposits

The KVC was host to 4 mines that exploited the local VMS deposits and includes the Kam Kotia Mine (MDI42A12SE00005), Jameland Mine (MDI42A12SE00003), Canadian Jamieson Mine (MDI42A12SE00009) and Genex Mine (MDI42A05NE00086) (*see* Figure 1). The production of each mine is reported in Table 2. Several mineral prospects and occurrences documented in the area (Ontario Geological Survey 2018) hint at the presence of VMS (for locations *see* Figure 1). According to the VMS model, lenses of massive sulphides can occur in a swarm at a contact between 2 volcanic units of different composition produced by a change of volcanism or a lull (Evans 1993). The KVC geology suggests such an environment is present—the change in volcanism is established by the compositional change in the rocks. Also, the mineralization that makes up these lenses is very dense and would have a marked gravity anomaly associated with it (Evans 1993). For the KVC, the gravity anomalies are not as pronounced as those found over the Kidd Creek Mine and that suggests a smaller tonnage and/or a more disseminated mineralization (Ontario Geological Survey 2004).

Table 2. Base metal production in the Kamiskotia Volcanic Complex Area (*modified from* van Hees 2018).

Mine	Township	Years of Production	Ore Milled	Grade
Canadian Jamieson	Godfrey	1966-1971	816 173 tons	2.44% Cu, 4.22% Zn
Genex	Godfrey	1966	Produced 240 tons Cu concentrate	
Jameland	Jamieson	1969-1972	509 356 tons	0.99% Cu, 0.88% Zn
Kam Kotia	Robb	1943-1944, 1961-1972	6.6 Mt	1.1% Cu, 1.17% Zn, 0.01 oz/t Ag, 0.00085 oz/t Au

Recommendation

The bush road where the altered rhyolite was found is located on the Whitesides esker (Richard 2000). The esker direction is north to south, and roughly follows the boundary between Côté–Robb and Byers–Loveland townships. That would put the source of this altered rhyolite sample at a location 5 to 10 km to the north of its point of collection, possibly near the intersection of the 4 townships. The exploration strategy should incorporate gravity geophysical technique, as proposed by van Hees et al. (2017), which would discriminate between massive sulphides and graphitic argillite.

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Massive Sulphide Deposits and Prospects Open for Staking

HIGHLIGHTS

- **86 Massive sulphide occurrences and prospects open for staking in Timmins District**
- **7 Massive sulphide occurrences and prospects open for staking in Sault Ste. Marie District**
- **Prospects might contain cobalt**

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Analysis of the Mineral Deposit Inventory (MDI) database (Ontario Geological Survey 2018) has identified 86 unstaked areas with massive sulphide mineral occurrences and prospects in the Timmins District and 7 in the Sault Ste. Marie District. They are prospective targets for exploration, especially for commodities such as cobalt. The total number of occurrences identified in this analysis indicates that there are still many unstaked areas with mineral occurrences and prospects in the Timmins District (138 were identified in 2017), as well as several in the Sault Ste. Marie District.

Unstaked nickel-copper and copper-zinc occurrences were identified first by selecting all mineral occurrences in the MDI database for the Timmins District that do not fall within the bounds of patented and leased claims (excluding those for surface rights only), withdrawn areas, and areas that are currently staked. The resulting data set was then examined using 2 queries: one for nickel and copper, which includes all occurrences and prospects with nickel or copper as a primary commodity (for cases where copper is the primary commodity, nickel must be listed as a secondary commodity for inclusion); and one for zinc and copper, where either copper or zinc are the primary commodity (copper-gold occurrences without zinc are omitted, as are any occurrences containing nickel). This analysis identified 52 unstaked areas with nickel-copper occurrences and one prospect; and 33 copper-zinc occurrences (information current to November 1, 2018). Some of these occurrences might contain cobalt concentrations in the 1000 to 2000 pm range (*see* van Hees 2018a, 2018b). Two maps showing the locations of unstaked occurrences were created: one for copper-zinc (VMS) occurrences (Figure 1) and the other for nickel-copper occurrences (Figure 2) in the Timmins District. Discretionary occurrences were omitted, although they also represent prospective targets. Fripp Township has the most copper-zinc occurrences open for staking, with three. McArthur Township has the most open nickel-copper occurrences with five.

The analysis of the Sault Ste. Marie District identified 2 unstaked areas with nickel-copper and 5 copper-zinc occurrences (information current to November 1, 2018). Although some of these occurrences might contain cobalt or PGEs, at this time no samples have been collected from these occurrences for geochemical analysis. Two maps showing the locations of unstaked occurrences in the Sault Ste. Marie District were created: one for copper-zinc (VMS) occurrences (Figure 3) and the other for nickel-copper occurrences (Figure 4). The 5 copper-zinc and 2 nickel-copper massive sulphide occurrences are all located in different townships with only one occurrence per township. It should be noted that 4 of the 7 occurrences are located within 250 m of staked ground.

The co-ordinates of the occurrences found in the MDI database used to generate these maps might be offset from their actual location on the ground. It is recommended that users of this volume “2018-2019 Recommendations for Exploration” consult the original documents and request RGP staff to verify the location of any occurrences.

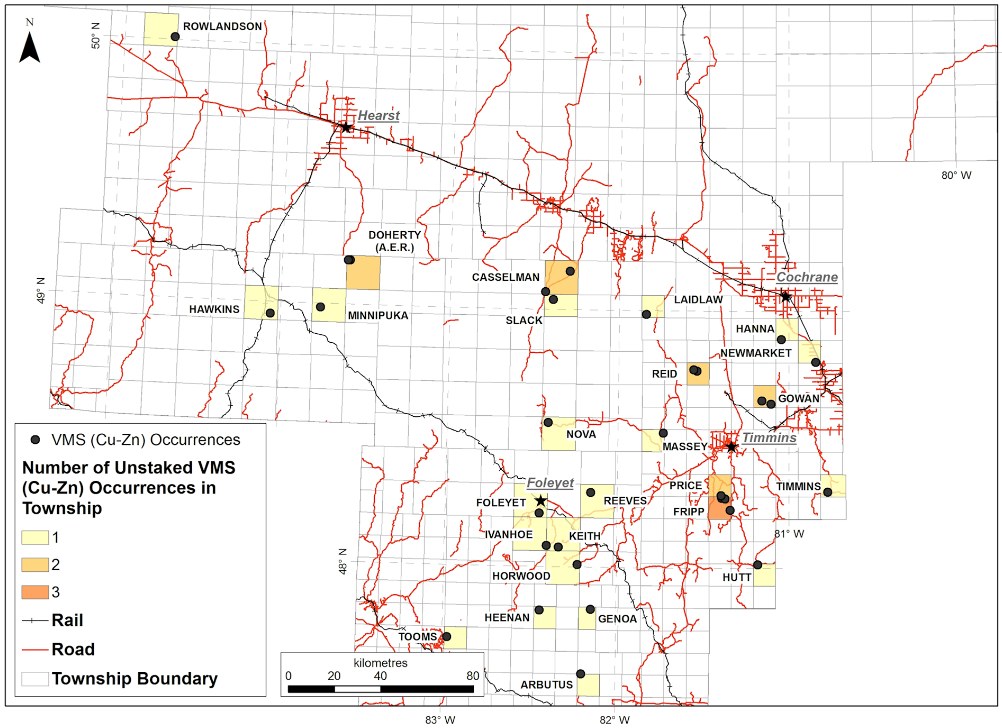

Figure 1. Areas of unstaked copper-zinc occurrences in the Timmins District (current to November 1, 2018).

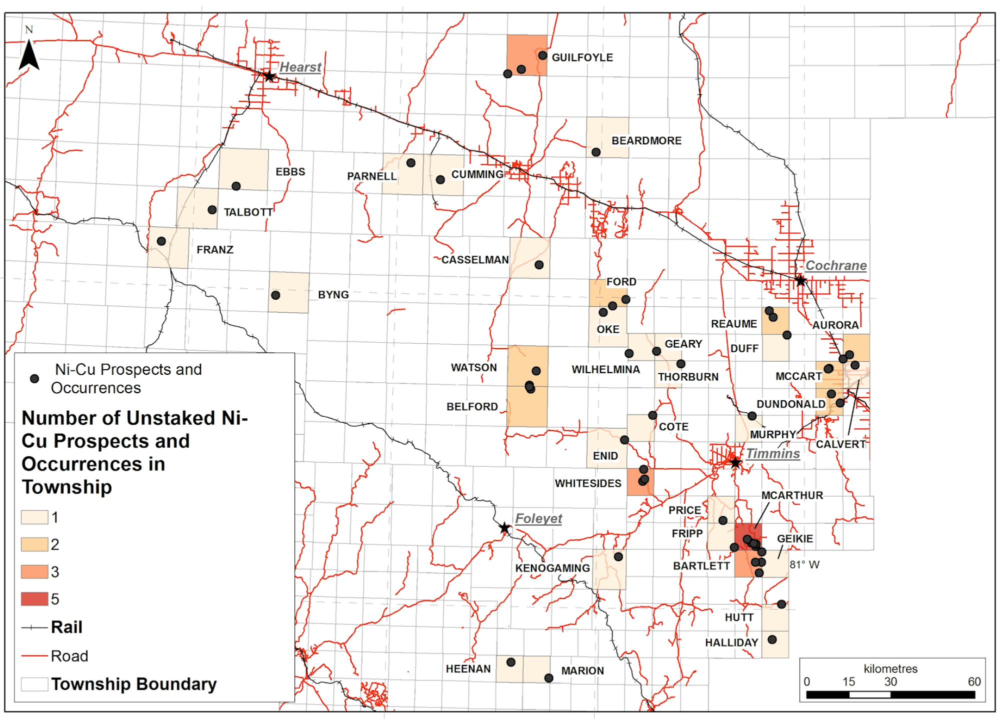

Figure 2. Areas of unstaked nickel-copper occurrences in the Timmins District (current to November 1, 2018).

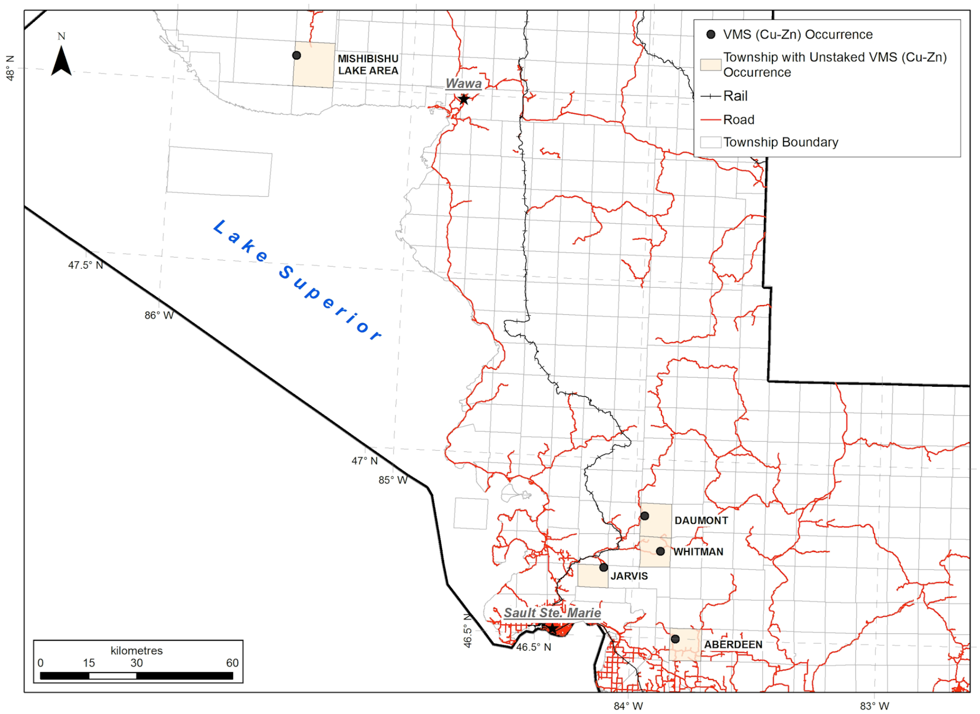

Figure 3. Areas of unstaked copper-zinc occurrences in the Sault Ste. Marie District (current to November 1, 2018).

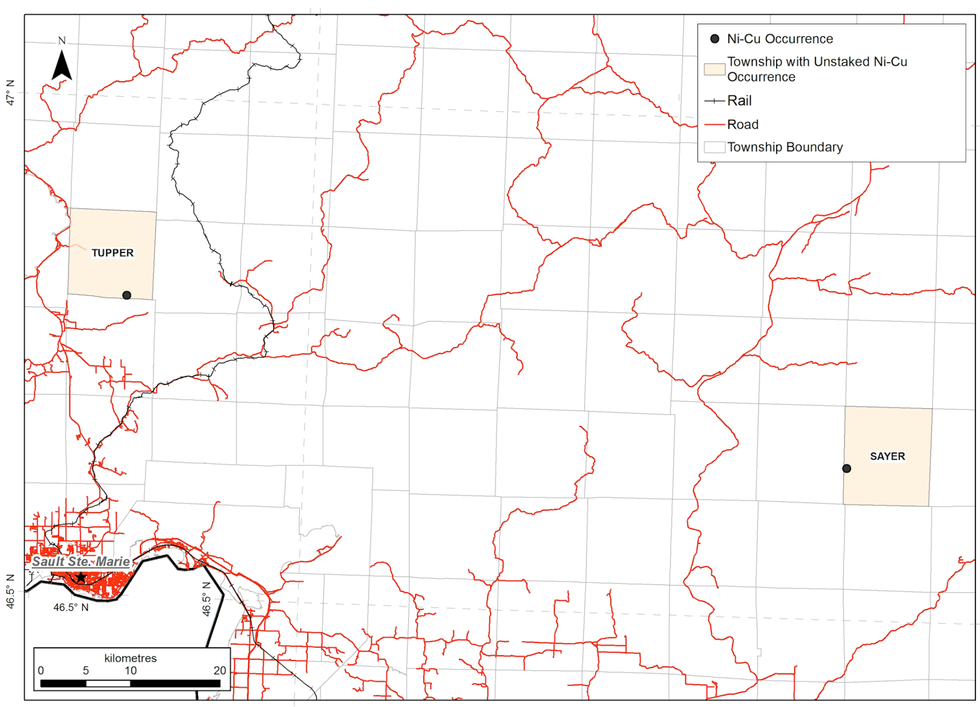

Figure 4. Areas of unstaked nickel-copper occurrences in the Sault Ste. Marie District (current to November 1, 2018).

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Exploration for Disseminated Nickel-Copper Mineralization

HIGHLIGHTS

- **Disseminated Cu-Ni mineralization might contain economic concentrations of metals**
- **Disseminated Cu-Ni mineralization probably generated by magmatic process**
- **Massive and disseminated Cu-Ni mineralization are chemically different and appear zoned**
- **Cu:Ni ratio zonation might be useful to explore for massive/higher grade mineralization**

Introduction

This study was initiated to determine the nature and extent of disseminated sulphide mineralization in Loveland Township drill-hole EC-16, where substantial copper-nickel-platinum group element (PGE) results were obtained from a massive sulphide sample collected at 320 feet (Table 1). If disseminated copper-nickel-PGE sulphide mineralization contains substantial amounts of metal, exploration for such deposits might 1) require a different geophysical strategy than the one used to look for massive sulphide mineralization and 2) uncover large, low-grade copper-nickel deposits.

Relevant Exploration History

Hollinger Consolidated Gold Mines Ltd. (Hollinger) explored for copper-nickel mineralization in Loveland Township using ground magnetic, very low frequency electromagnetic (VLF–EM16) and Turam geophysical surveys, as well as geological mapping. Weak coincident magnetic (100γ) and VLF–EM anomalies, but no Turam EM anomaly (Bosschart 1964), occur in the area northeast of Enid Creek between survey lines 10+00 feet and 24+00 feet (305 and 732 m) south and was drill tested by a number of drill holes, including EC-16 (MacKenzie 1964, 1966, 1967, 1968).

Diamond-drill hole EC-16 (454130E 5389330N) is a vertical hole drilled to test the northern extent of a copper-nickel mineralized zone encountered in drill-holes EC-1 to EC-15, inclusive (Vanderklift, Van Luven and Voormeij 2005). Drill-hole EC-16 intersected 3 feet (0.91 m) of massive sulphide between 320 and 323 feet that contained an average of 1.46% Ni and 0.35% Cu (MacKenzie 1968; Vanderklift, Van Luven and Voormeij 2005). Drilling in this hole also encountered 5 feet (1.5 m) of disseminated copper-nickel mineralization between 315 and 320 feet that contained 0.49% Ni and 0.09% Cu and 1 foot (0.3 m) of disseminated copper-nickel mineralization between 224 and 225 feet that contained 0.14% Ni and 0.09% Cu (MacKenzie 1968; Vanderklift, Van Luven and Voormeij 2005).

Drill Core Geology

Diamond-drill hole EC-16 crosscut 4 different rocks units, including 1 logged as andesite and 3 logged as different types of gabbro (quartz, basic and mottled) (MacKenzie 1968; Vanderklift, Van Luven and Voormeij 2005). It also intersected disseminated sulphide mineralization between 225 and 325 feet (for metric equivalents *see* Tables 1 and 2) that was estimated visually to contain 0.1 to 8.0% pyrrhotite and minor chalcopyrite. Massive and disseminated mineralization was sampled between 315 and 325 feet and disseminated mineralization was sampled between 224 and 225 feet (MacKenzie 1968). The drill log lacks detail, but does indicate that the sulphide mineralization is hosted by 3 types of gabbro and there is a volcanic unit beneath (down hole) the intrusive rocks.

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Sampling and Analytical Details

Telescoped diamond-drill core, consisting of samples 2 inches (5 cm) in length, was collected every 5 feet (approximately 1.5 m) from drill-hole EC-16 and was donated to the Timmins District Core Library for assessment credit. Core samples used for this study were collected from 200 to 350 feet, and submitted to the OGS Geoscience Laboratories in Sudbury to determine the concentration of the following elements by inductively coupled plasma mass spectrometry (ICP–MS, method IML-100, aqua regia leachate): silver, arsenic, gold, bismuth, cadmium, cobalt, copper, mercury, indium, iridium, molybdenum, nickel, lead, palladium, platinum, rhodium, antimony, selenium, tin, tellurium, titanium and zinc; and sulphur content using method IRC-100. The gold, iridium, palladium, platinum and rhodium content of the sample taken at 320 feet was determined using the IMP-200 (nickel sulphide fire assay) method. The IML-100 method costs 80% less than the IMP-200 method. Selected analytical results are provided in Table 1.

Results and Discussion

A massive sulphide sample collected at 320 feet (97.5 m) contained 21 290 ppm Ni, 1926 ppm Cu, 1480 ppm Co, 2.06 ppm Pd and 0.32 ppm Pt (see Table 1). Disseminated sulphide copper-nickel mineralization between 225 and 315 feet (69.6 and 96 m) contains an average of 0.19% Cu + Ni (0.108% Cu plus 0.086% Ni) (see Table 1) and 0.130 ppm Au + PGEs (Au, plus Pd, Pt and Rh) over 95 feet (29 m). Average palladium content of 0.099 ppm Pd accounts for 75% of the total Au + PGEs. Iridium content is below detection limit (0.003 ppm Ir) for all samples. The average cobalt content, 78 ppm Co, is only 3 times the crustal abundance (Wedepohl 1995).

The average Cu:Ni ratio is 1.8 from 200 to 275 feet and 0.5 from 280 to 315 feet. A massive sulphide sample collected at 320 feet has a Cu:Ni ratio of 0.09. The increase in Cu:Ni ratios from 0.09 to 0.5 and then to 1.8, upward in the drill hole, indicates that the sulphide mineralization is zoned, with nickel-rich mineralization near the base changing to copper-rich mineralization near the top. The Cu:Ni ratio zonation present in the disseminated and massive mineralization might be useful as a vector toward massive sulphides when exploring disseminated mineralization.

The Pd:Pt ratios, that range from 3.3 to 16.9 and average 11.4, were determined for 13 samples that had measurable Pd or Pt concentrations. There is no obvious zonation in Pd:Pt ratios comparable to those seen in the Cu:Ni ratios. The high Pd:Pt ratio (>5) in drill-hole EC-16, the absence of measurable iridium, as well as bismuth, selenium and tellurium contents that are 1, 13 and 44 times, respectively, greater than average crustal abundance (Wedepohl 1995) are interpreted to indicate deposition by a Bushveld Complex-like magmatic process (Godel, Barnes and Maier 2007).

The samples between 225 and 315 feet, a 100-foot (30.5 m) interval, contains an average of 0.5% S (see Table 1), consistent with the estimated pyrrhotite content. The 100-foot (30.5 m) mineralized zone has a calculated true width of 70 feet (21.3 m) because drill-hole EC-16 is vertical and the gabbro appears to dip approximately 45° east (MacKenzie 1968; Vanderklift, Van Luven and Voormeij 2005).

The 2-inch (5 cm) lengths of core samples available are interpreted to represent 5-foot intervals of core. The sample at 320 feet is the only exception to this interpretation and probably represents only a 3-foot (0.91 m) long intercept of massive sulphide that was logged by MacKenzie (1968).

The 100-foot (30.5 m) intercept (Table 2: indicated by vertical line) contained metals worth a total of US$46.43 (C$60.83) per tonne on November 5, 2018. If the 60% greater specific gravity of massive pyrrhotite compared to disseminated sulphide samples (4.6 versus 2.9 g/cc) is considered, it will increase the estimate of total metal value to nearly US$60.00 per tonne. If the sample collected at 320 feet only represents a 2.5-foot zone of massive sulphides, the metal value estimate of the 100-foot (30.5 m) intercept will be only US$35.41 per tonne (not taking specific gravity into account). A mineralized zone with a true width of 70 feet (21.3 m) containing US$46.43 of metal per tonne would be comparable to an intercept containing 1.17 g/t Au. Such a deposit would have a higher grade than the 0.97 g/t Au mined at the Detour Gold Mine in 2017 (Detour Gold Corporation, news release, January 16, 2018) or the estimated grade of 1.07 g/t Au of reserves in the Goldcorp Century pit project (Goldcorp Inc., Investor Day 2018 presentation, January 16, 2018). Such metal values are comparable in value to the proven nickel reserve (0.32% Ni) in the geologically different Dumont deposit in Quebec (Staples et al. 2013) and could trigger a paradigm shift toward open-pit mining of disseminated copper-nickel mineralization.

The average PGE content of the 100-foot (25.9 m) intercept accounts for 18.4% of the total dollar value.

Table 1. Geochemistry of Loveland diamond-drill core EC-16.

DDH (feet)	DDH (metres)	S (%)	Cu (ppm)	Ni (ppm)	Co (ppm)	Au (ppm)	Pd (ppm)	Pt (ppm)	Rh (ppm)	Bi (ppm)	Se (ppm)	Te (ppm)	Cu+Ni (%)	Cu:Ni ratio	Pd:Pt ratio
Detection Limit:		*0.003*	*0.6*	*2*	*0.03*	*0.002*	*0.02*	*0.005*	*0.003*	*0.02*	*0.2*	*0.02*			
200	61.0	0.01	38	181	33	0.014	bdl	0.005	0.005	0.02	bdl	0.02	0.02	0.21	
205	62.5	0.12	164	181	30	0.011	bdl	bdl	0.009	0.03	0.3	0.04	0.03	0.91	
210	64.0	0.09	52	197	29	0.008	bdl	bdl	bdl	bdl	0.2	bdl	0.02	0.26	
215	65.5	0.08	27	353	43	0.002	bdl	bdl	0.004	0.02	0.4	0.02	0.04	0.08	
220	67.1	0.03	267	134	21	0.005	bdl	bdl	0.007	bdl	bdl	0.02	0.04	1.99	
225	68.6	1.04	2179	1157	113	0.010	0.05	bdl	0.003	0.05	2.5	0.25	0.33	1.88	
230	70.1	0.23	1040	236	31	0.006	bdl	0.005	0.01	0.02	0.8	0.11	0.13	4.41	
235	71.6	0.24	461	353	34	0.003	0.02	0.006	0.006	0.03	0.9	0.1	0.08	1.31	3.3
240	73.2	2.23	3671	2477	181	0.050	0.21	0.017	0.007	0.13	5.9	0.80	0.61	1.48	12.1
245	74.7	2.26	5351	2427	140	0.095	0.16	0.010	bdl	0.06	5.4	0.52	0.78	2.20	16.0
250	76.2	0.12	353	283	52	0.007	0.04	0.005	0.007	0.02	0.5	0.07	0.06	1.25	8.0
255	77.7	0.24	510	388	42	0.004	0.09	0.007	bdl	0.05	0.7	0.2	0.09	1.31	12.9
260	79.2	0.28	638	357	39	0.003	0.13	0.009	0.015	0.07	0.9	0.26	0.10	1.79	14.4
265	80.8	0.12	585	279	41	0.002	0.03	bdl	0.003	bdl	0.4	0.06	0.09	2.10	
270	82.3	0.03	140	315	42	bdl	bdl	bdl	bdl	bdl	0.2	0.02	0.05	0.44	
275	83.8	0.78	2681	1367	154	0.031	0.19	0.013	0.007	0.06	2.9	0.49	0.40	1.96	15.2
280	85.3	0.17	390	833	82	0.008	0.08	0.009	0.003	0.03	0.6	0.12	0.12	0.47	8.9
285	86.9	0.23	783	602	59	0.004	0.16	0.01	0.009	0.04	0.9	0.27	0.14	1.30	16.0
290	88.4	0.01	34	285	44	bdl	0.03	bdl	0.005	bdl	bdl	0.03	0.03	0.12	
295	89.9	0.11	167	412	55	0.003	0.03	0.006	bdl	0.04	0.6	0.12	0.06	0.41	5.0
300	91.4	0.05	217	352	50	0.002	bdl	bdl	0.01	0.02	0.2	0.03	0.06	0.62	
305	93.0	0.03	143	544	65	0.002	0.02	bdl	0.005	0.02	0.2	0.05	0.07	0.26	
310	94.5	0.12	265	884	82	0.005	0.14	0.016	0.005	0.07	0.5	0.21	0.11	0.30	8.4
315	96.0	1.25	941	2774	185	0.004	0.22	0.013	0.022	0.13	3.8	0.47	0.37	0.34	16.9
320	97.5	28.33	1926	21290	1480	0.014	2.055	0.317	0.016	1.77	33.4	7.33	2.32	0.09	6.5
325	99.1	0.03	182	45	9	0.002	bdl	bdl	0.006	bdl	bdl	0.02	0.02	4.04	
330	100.6	0.02	54	43	11	bdl	bdl	bdl	0.014	bdl	bdl	bdl	0.01	1.26	
335	102.1	0.03	34	54	21	0.002	bdl	bdl	bdl	bdl	bdl	bdl	0.01	0.63	
340	103.6	0.01	48	46	19	bdl	bdl	bdl	bdl	bdl	bdl	bdl	0.01	1.04	
345	105.2	0.01	71	51	20	bdl	bdl	bdl	0.006	bdl	bdl	bdl	0.01	1.39	
350	106.7	0.02	151	34	14	bdl	bdl	bdl	0.006	bdl	bdl	bdl	0.02	4.49	

Abbreviation: bdl = below detection limit.

Table 2. Value of metals in Loveland diamond-drill core EC-16.

		Cu	Ni	Co	Au	Pd	Pt	Rh			
	Metal Price:	2.816 (US$/lb)	5.502 (US$/lb)	27.33 (US$/lb)	39.54 (US$/g)	35.14 (US$/g)	26.52 (US$/g)	31.37 (US$/g)			
Depth (feet)	**Depth** (metres)	**Cu Value** (US$/t)	**Ni Value** (US$/t)	**Co Value** (US$/t)	**Au Value** (US$/t)	**Pd Value** (US$/t)	**Pt Value** (US$/t)	**Rh Value** (US$/t)	**Total Value** (US$/t)	**Avg. Value** (US$/t)	**Avg. Value** (US$/t)
200	61	0.24	2.2	1.99	0.55	0	0.13	0.16	5.26		
205	62.5	1.02	2.19	1.83	0.42	0	0	0.28	5.73		
210	64	0.32	2.39	1.77	0.32	0	0	0	4.8		
215	65.5	0.17	4.28	2.61	0.08	0	0	0.13	7.27		
220	67.1	1.66	1.63	1.28	0.2	0	0	0.22	4.98		
225	68.6	13.53	14.03	6.8	0.4	1.76	0	0.09	36.61		
230	70.1	6.46	2.86	1.89	0.24	0	0.13	0.31	11.89		
235	71.6	2.86	4.28	2.06	0.12	0.7	0.16	0.19	10.37		
240	73.2	22.79	30.04	10.91	1.96	7.2	0.45	0.22	73.57	**31.73**	
245	74.7	33.22	29.44	8.4	3.76	5.62	0.27	0	80.71		
250	76.2	2.19	3.43	3.1	0.28	1.41	0.13	0.22	10.76		
255	77.7	3.17	4.71	2.51	0.16	3.16	0.19	0	13.89		
260	79.2	3.96	4.33	2.34	0.12	4.57	0.24	0.47	16.03		
265	80.8	3.63	3.38	2.46	0.08	1.05	0	0.09	10.7		**46.43**
270	82.3	0.87	3.82	2.52	0	0	0	0	7.21		
275	83.8	16.64	16.58	9.28	1.23	6.68	0.33	0.22	50.96		
280	85.3	2.42	10.1	4.95	0.32	2.81	0.24	0.09	20.93	**31.31**	
285	86.9	4.86	7.3	3.55	0.16	5.62	0.27	0.28	22.04		
290	88.4	0.21	3.46	2.64	0	1.05	0	0.16	7.52		
295	89.9	1.04	5	3.34	0.12	1.05	0.16	0	10.7		
300	91.4	1.35	4.27	2.98	0.08	0	0	0.31	8.99		
305	93	0.89	6.6	3.9	0.08	0.7	0	0.16	12.33		
310	94.5	1.64	10.72	4.94	0.2	4.74	0.42	0.16	22.82	**133.95**	
315	96	5.84	33.65	11.17	0.16	7.73	0.34	0.69	59.58		
320	97.5	11.96	258.24	89.17	0.55	72.21	8.41	0.5	441.05		
325	99.1	1.13	0.55	0.54	0.08	0	0	0.19	2.49		
330	100.6	0.34	0.52	0.67	0	0	0	0.44	1.97		
335	102.1	0.21	0.66	1.28	0.08	0	0	0	2.22		
340	103.6	0.3	0.56	1.14	0	0	0	0	1.99		
345	105.2	0.44	0.62	1.2	0	0	0	0.19	2.45		
350	106.7	0.93	0.41	0.83	0	0	0	0.19	2.35		

All metal prices are bid values obtained from London Metals Exchange, Kitco and Metals Bulletin on November 5, 2018.
Abbreviation: Avg. = average.

Recommendations

Core containing disseminated copper-nickel mineralization with less than 5% sulphides should be analyzed using a multi-element ICP–MS analytical package containing both base metals and PGEs. Zonation of Cu:Ni ratios should be assessed and used to search for nearby massive copper-nickel mineralization.

Attention should be paid to weak magnetic and VLF–EM anomalies near known copper-nickel mineralization. Such anomalies might be tested using induced polarization to identify both disseminated and thin massive sulphide zones.

Conclusions

- Hollinger drill-hole EC-16 has an average Cu plus Ni content of 0.19 weight % Cu+Ni over 100-foot (30.5 m) core length or 70 feet (21.3 m) true width.
- Cu:Ni ratio zonation is present in the disseminated mineralized zone and might be useful as a vector pointing toward massive sulphide mineralization.
- The Pd:Pt ratio, absence of measurable iridium, and total bismuth, selenium and tellurium content indicate a magmatic process.
- The total metal value in the disseminated zone is estimated to be US$46.43 per tonne and would be comparable to 1.17 g/t Au (November 5, 2018 metal values).
- Average gold plus PGE content in the disseminated zone accounts for 18.4% of total metal value.

Cautionary Statement

Analytical results for the 5 cm (2-inch) length core samples collected are interpreted to represent 1.5 m (5-foot) intervals of core. This assumption is thought to be valid for most samples. The sample collected at 320 feet was obtained from 3 feet (0.91 m) of core containing massive sulphides (MacKenzie 1968; Vanderklift, Van Luven and Voormeij 2005). Given that the massive sulphide intercept is less than 5 feet (1.5 m), the value of the 100-foot (30.5 m) intercept is somewhat overestimated.

Post-Publication Addendum and Errata

In January 2023, following publication (in December 2022) of additional related analytical data, the Timmins Resident Geologist Office staff were contacted about the content of this recommendation. After a search of the Timmins Drill Core Library, staff found there existed 2 separate boxes of donated company drill core, both labelled as "box 155406". One box contained core from drill-hole L-13 and the other box contained core from drill-hole EC-16. Further investigation revealed that the drill core studied in this project was, in fact, from drill-hole EC-16, rather than from drill-hole L-13. The analytical data reported have not been affected; however, the location of the drill hole, the description of the geology and resultant interpretations required extensive modifications. This version, as of February 2023, corrects the errors.

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HIGHLIGHTS

- **Excellent potential for PGE mineralization - platinum and palladium**
- **Previously under-explored, with District-scale targeting as a first-pass review**
- **Combination of good geological structure and sizeable mafic intrusive emplacement**
- **Significant PGE assay values in historic databases and reports**

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PGEs – Let's Take Another Look in the Kirkland Lake District

Here we take a District-wide look into the world of platinum group elements (PGE)—more specifically, the distribution of platinum (Pt) and palladium (Pd) in the Kirkland Lake area. This synopsis was prompted by a review of the various lithogeochemical databases held in the Kirkland Lake Resident Geologist Office and the relative scarcity of data compared to gold and the base metals. Until recently, geochemical analysis of PGE was prohibitively costly, and may well have been a deterrent to explorers at the time. This is no longer the case.

Table 1 lists anomalous PGE occurrences, as reported in historic in-house databases and the Mineral Deposit Inventory (MDI) database (Ontario Geological Survey 2018), based on a combined average of Pt and Pd values, (Pt+Pd)/2, that exceed 100 parts per billion (ppb), along with their ratios, Pd/Pt, and concentrations in ppb. These anomalies are plotted on a modified geological map of the District in Figure 1 (Ayer and Chartrand 2011), which illustrates their spatial relationship to the occurrences of Neo- to Mesoarchean age intrusive mafic rocks, predominantly gabbro and anorthosite, regarded as suitable hosts for PGE mineralization (Eckstrand et al. 2007). Potential PGE target areas are outlined in blue boxes and further discussed below.

The reader is referred to the classification of mafic–ultramafic intrusions in Ontario and their implications for PGE mineralization by Vaillancourt et al. (2002), with examples more relevant to the District listed in Table 2 and the enlarged target areas illustrated in Figures 2, 3 and 4.

As shown in Figure 1, anomalous PGE mineralization can be associated with mafic dike swarms and sills (described by Meyer et al. 1999) in addition to some of the more regionally extensive mafic intrusive bodies. The locality of the stratiform River Valley palladium deposit in the adjacent Sudbury District (to the south) is also shown.

Table 1. Anomalous platinum and palladium occurrences in the Kirkland Lake Resident Geologist District for average values (Pt+Pd/2) greater than 100 ppb, as recorded in historic in-house lithogeochemical databases and the Mineral Deposit Inventory database (MDI, *see* Ontario Geological Survey 2018). Location of the occurrences in Figure 1 are keyed to the Ref # in the table. Universal Transverse Mercator (UTM) co-ordinates are provided using North American Datum 1983 (NAD83) in Zone 17.

Ref #	Sample #	MDI #	Easting (mE)	Northing (mN)	Pd (ppb)	Pt (ppb)	(Pt+Pd)/2 (ppb)	Pd/Pt
1	GG09601		573254	5201429	61888	83	30985	749.2
2	13DLG01A	MDI31M04SW00022	587583	5217381	5000	10580	7790	0.5
3	JSM-886	MDI42A02SW00063	513417	5327720	5162	2427	3795	2.1
4	14DLG02B	MDI31M04SW00022	587571	5217425	3861	1482	2672	2.6
5	15DLG011A	MDI41I15SW00069	509120	5183170	1836	1168	1502	1.6
6	GG09646	MDI31M04SW00022	587566	5217396	2308	401	1355	5.8
7	9301	MDI41I16NE00004	573620	5201530	1578	26	802	61.7
8	98303	MDI42A07SE00007	529492	5344503	1208	251	730	4.8
9	15DLG019B		507165	5313901	351	143	247	2.5
10	GG06618		507142	5313899	261	146	203	1.8
11	5309		507188	5313912	252	132	192	1.9
12	10345		486819	5267352	171	148	160	1.1
13	83AJM-0217		538448	5472949	195	24	110	8.1
14	1331		563448	5323779	116	92	104	1.3
15	GG03615	MDI41P11NE00023	556282	5288929	154	44	99	3.5

Table 2. Mineralization types, locations, tectonic settings, composition and ages of representative PGE mineralized intrusions in Ontario (*modified from* Vaillancourt et al. 2002).

Mineralization Type	Example	Tectonic Subdivision	Tectonic Setting	Composition	Age (Ga)
Stratiform contact	River Valley	SP	CR	M > UM	2.5
	Nipissing Diabase	—	dike swarm	M >> UM	2.2
	Coldwell Complex	MCR	CR	F-I >> M	1.1
Stratiform reef	Nordica	AGB	RA	UM ~ M	2.7
	Centre Hill Complex	AGB	RA	M ~ UM	2.7
Hydrothermally mobilized magmatic	Lac des Iles	WBG	RA	M >> UM	2.7
Other	Otto Stock	AGB	RA	F-I > M	2.7
	Abitibi Batholith	AGB	RA	M > UM	2.7

Tectonic subdivision: AGB = Abitibi greenstone belt; MCR = Mid continental rift; SP = Southern Province; WBG = Wabigoon
Tectonic setting: CR = continental rift, RA = rifted arc; Composition: F = felsic, I = intermediate, M = mafic, UM = ultramafic.

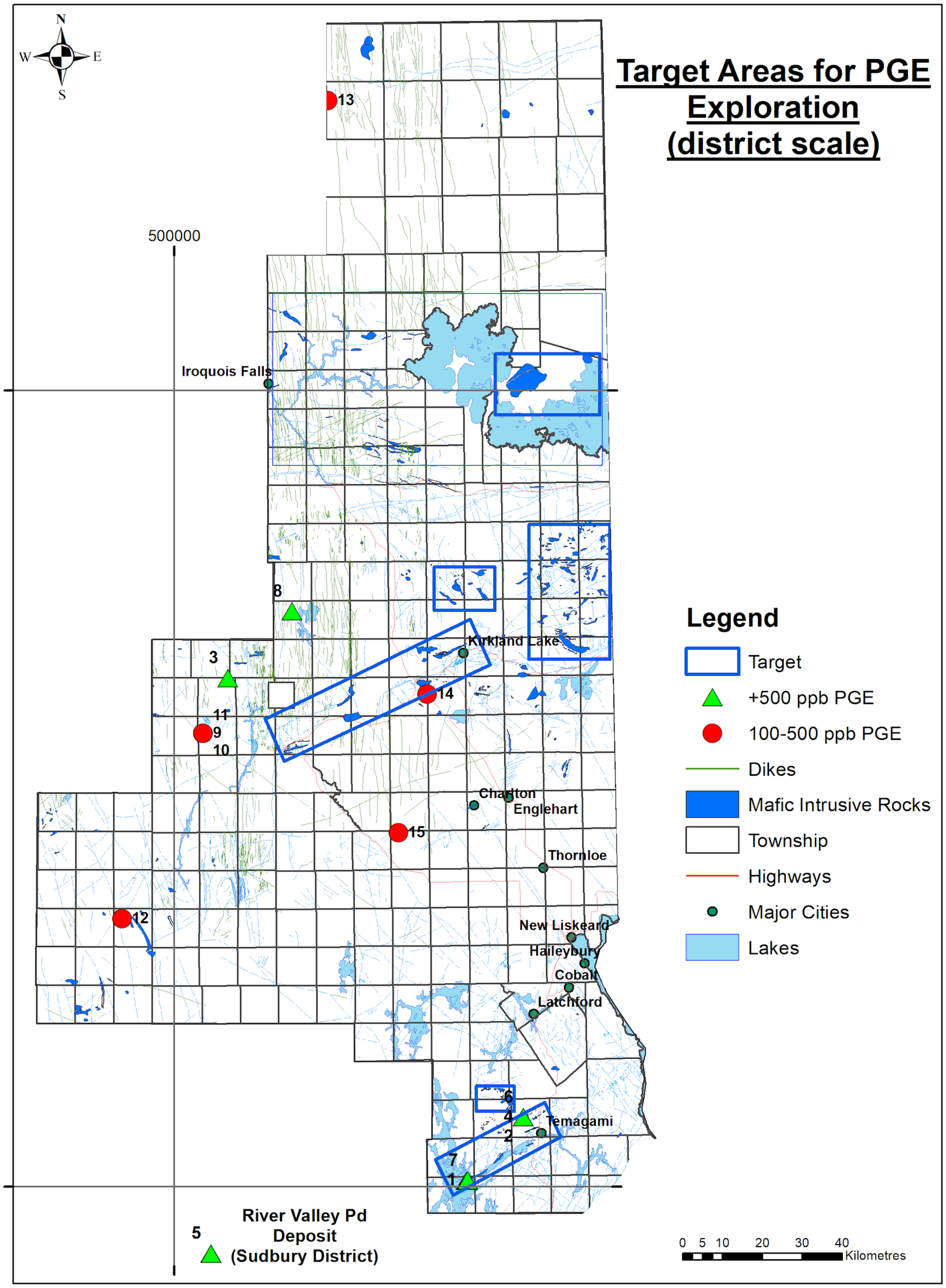

Figure 1. A geological map of the Kirkland Lake District (modified from Ayer and Chartrand 2011), showing location of mafic intrusive rock and anomalous PGE (platinum and palladium) occurrences, cross listed with Ref # in Table 1. Universal Transverse Mercator (UTM) co-ordinates are using North American Datum 1983 (NAD83) in Zone 17.

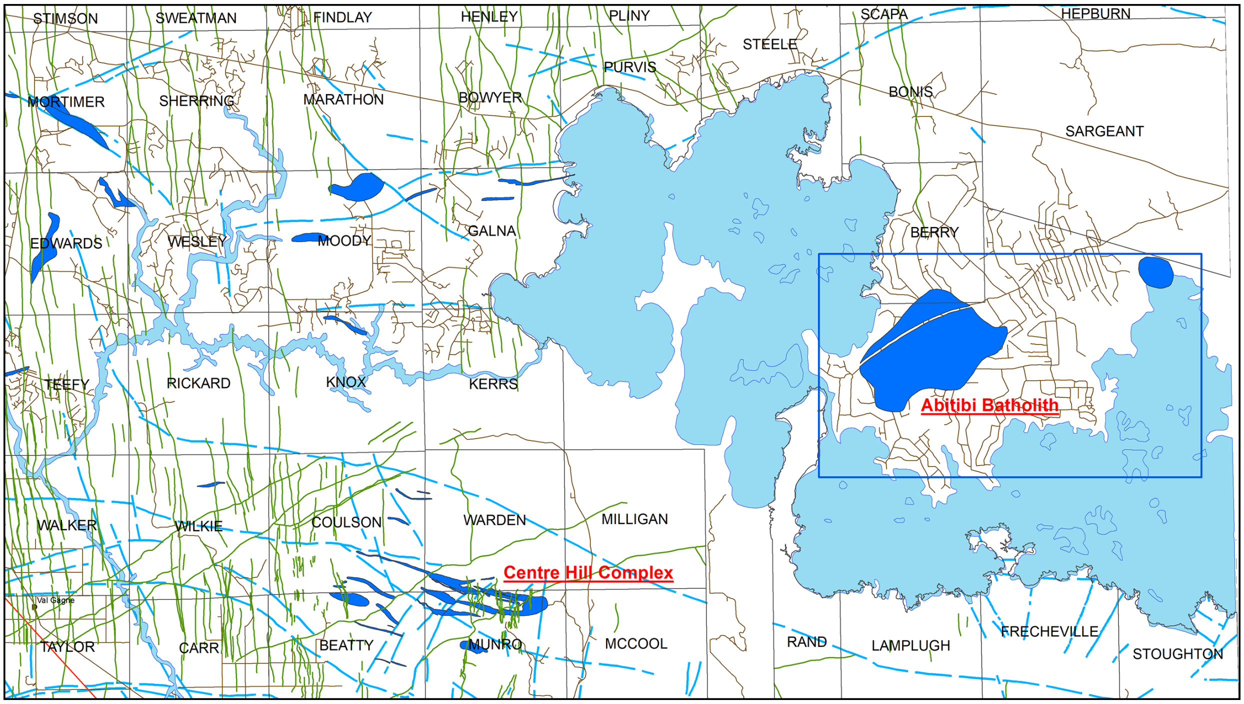

Figure 2. Prospective mafic intrusive targets (bound in blue box), in the Lake Abitibi batholith area, considered to be favourable hosts for PGE mineralization, as described by Good (1987) and Smith and Sutcliffe (1988); *see* map legend in Figure 1.

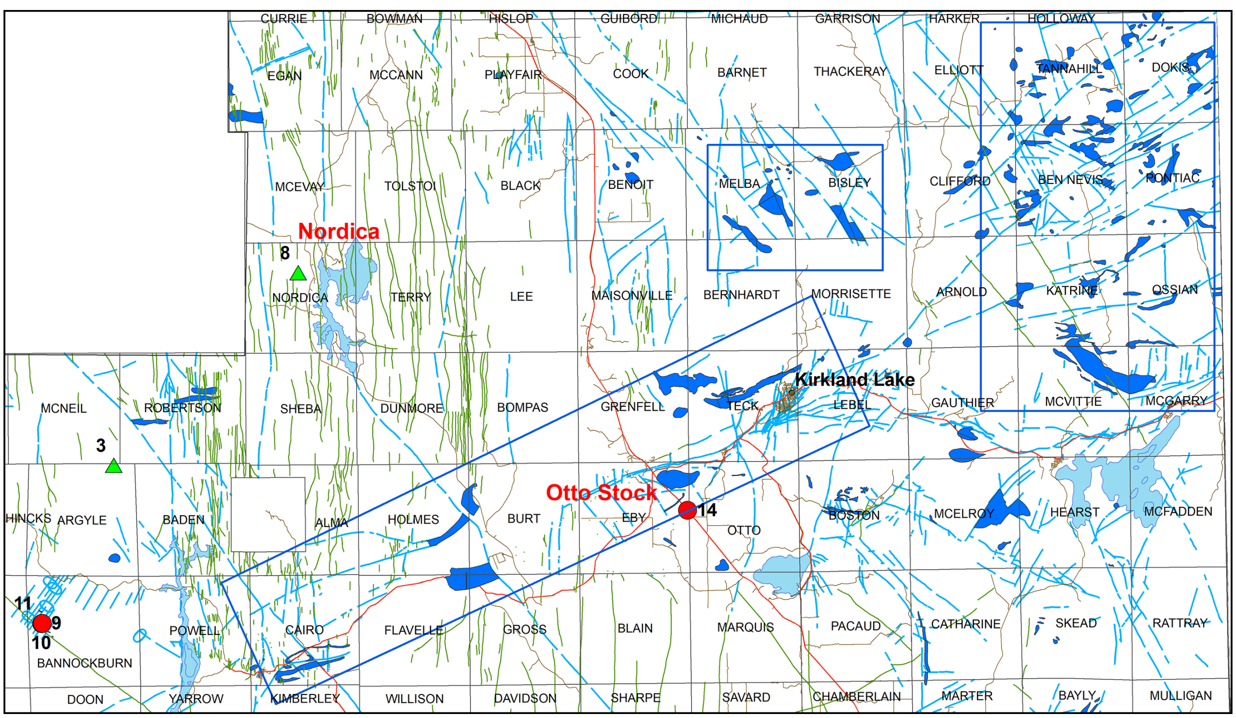

Figure 3. Prospective mafic intrusive rocks in the Kirkland Lake area, with a strong association with key geological structures, described by Smith and Sutcliffe (1988); potential PGE targets bound in blue boxes; *see* map legend in Figure 1 and occurrence Ref# in Table 1.

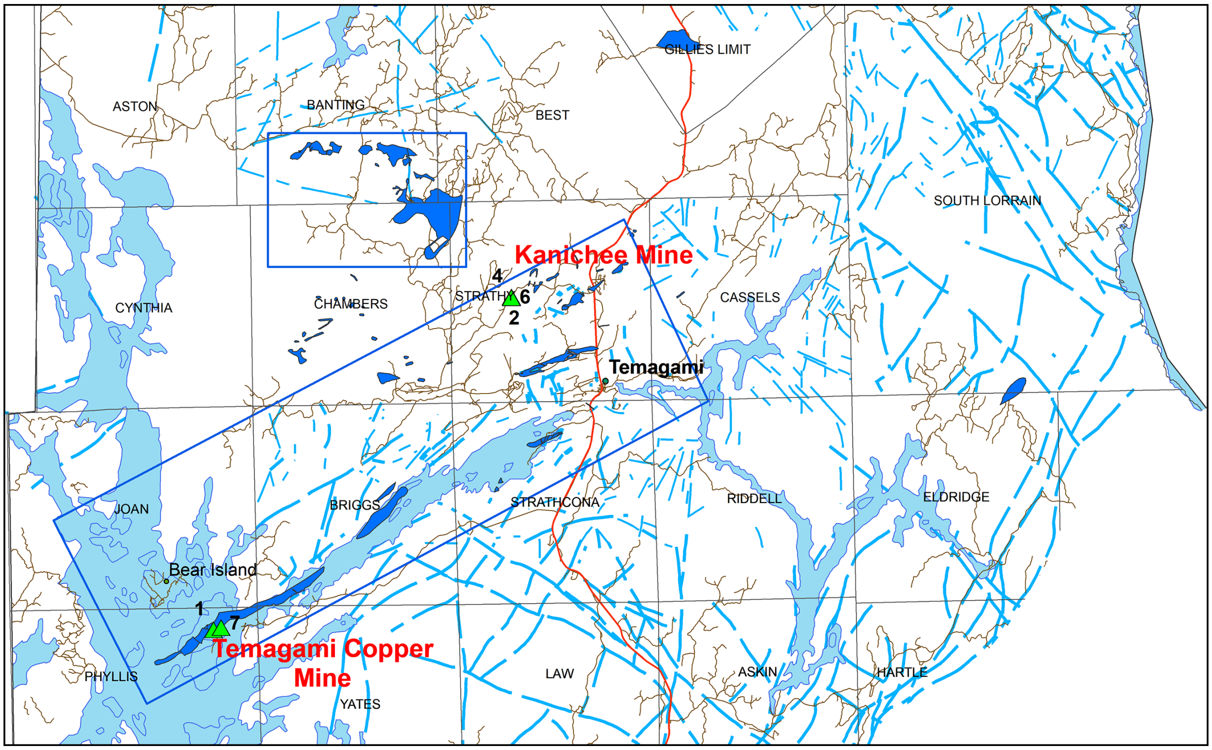

Figure 4. Prospective mafic intrusive rocks in the Temagami area, described by Guindon et al. (2014); potential PGE targets bound in blue boxes; *see* map legend in Figure 1 and occurrence Ref# in Table 1.

As indicated in Table 2, PGE mineralization can be found in mafic to ultramafic layered intrusions (approximately 2.7 Ga) common within the Abitibi greenstone belt, in addition to the Nipissing diabase (approximately 2.2 Ga) and associated dike swarms (Vallaincourt et al. 2002). Of interest is the linear alignment of the River Valley palladium deposit (approximately 2.5 Ga), *see* Figure 1, also described by Vallaincourt et al. (2002), with anomalous PGE occurrences in the Temagami area.

James et al. (2002) describe the common occurrence and significance of high Pd:Pt ratios associated with PGE mineralization within the Nipissing gabbro (diabase), with Pd:Pt ratios in mineralized samples of about 5:1, with very high PGE concentrations (i.e., greater than 7000 ppb) showing very high Pd:Pt ratios (i.e., greater than 10:1). Anomalous PGE values reported in Table 1 tend to have relatively high Pd:Pt ratios, and might suggest an association with the Nipissing diabase or at least the type or style of mineralization associated with it.

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HIGHLIGHTS

- **25 years of recommendations for exploration in the Kirkland Lake area**
- **A review of past recommendations for gold, PGE, base metals and kimberlite**
- **Revisit exploration tips and clues**

25 Years of Exploration in the Kirkland Lake Area: Tips, Hints and Clues

Every now and then it is good to reflect on where we've been over the past decades and to harvest the many years of knowledge and experience of staff past and present. To recap on ideas that were possibly considered to be new and adventurous in the day but may well be taken for granted now. The reader may wish to review some of the previous recommendations for exploration as listed in Table 1, if only to check that nothing was missed, or hopefully to re-kindle some interest in a commodity or geographic area.

The challenge is now with us, the staff of the Kirkland Lake Resident Geologist Office, to look at areas not previously looked at, to consider new technologies that are becoming available and to hopefully come up with some novel and somewhat innovating exploration tips, hints and clues in the next 25 years to come!

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Table 1. A list of all recommendations for exploration by the Resident Geologist Program, in the Kirkland Lake area from 1992 to 2017. Abbreviations: MP, Miscellaneous Paper; OFR, Open File Report

Year	Title	MP/OFR	Reference	Commodity
1992	"Blind" epigenetic gold deposit exploration	MP 161	Schneider et al 1993	Epigenetic Au
1993	Gold in Matheson area and Gauthier Twp.	OFR 5892	Baker et al. 1994	Au
1994	Victoria Creek gold zone	OFR 5921	Baker et al. 1995	Au
1995	Low-grade open pit potential – Fenn–Gibb, Y-D type	OFR 5943	Baker et al. 1996	Au
1996	Highway 101 corridor gold	OFR 5958	Newsome et al. 1997	Au
1997	Massive sulphide mineralization Matheson area	OFR 5973	Meyer et al. 1998	VMS
1998	Enhanced aeromagnetic data in Lebel and Gauthier Twps. Tool for gold exploration	OFR 5991	Meyer et al. 1999	Au
1998	PGE-Cr potential in Nordica, McEvay and Sheba Twps.	OFR 5991	Meyer et al. 1999	PGE - Cr
1998	Untested gold potential of the North Branch of the Destor–Porcupine Fault Zone	OFR 5991	Meyer et al. 1999	Au
1999	Allsopp–Huston gold property	OFR 6007	Meyer et al. 2000	Au
1999	Copper-nickel-PGE mineralization Temagami area	OFR 6007	Meyer et al. 2000	PGE - Cu - Ni
1999	Epidote alteration with possible VMS association in Maisonville Twp.	OFR 6007	Meyer et al. 2000	VMS
1999	Potential new gold camp in Lake Abitibi area	OFR 6007	Meyer et al. 2000	Au
2000	Using "Operation Treasure Hunt" data to search for kimberlite pipes	OFR 6051	Meyer et al. 2001	Kimberlite
2000	Potential new gold camp in Lake Abitibi area	OFR 6051	Meyer et al. 2001	Au
2000	Diamond potential and lamprophyre in the Lake Timiskaming structural zone	OFR 6051	Meyer et al. 2001	Kimberlite
2001	Exploration for diamonds	OFR 6083	Meyer et al. 2002	Kimberlite
2002	Iron-oxide-copper-gold potential (in the Huronian Supergroup)	OFR 6114	Meyer et al. 2003	IOCG
2002	Additional barite potential in Yarrow Twp.	OFR 6114	Meyer et al. 2003	Barite
2002	Assessment of volcanic/sedimentary rocks for Cu-Zn-Pb potential in Shining Tree area	OFR 6114	Meyer et al. 2003	Cu-Zn-Pb
2002	Diamond potential and lamprophyre in the Lake Timiskaming structural zone - update	OFR 6114	Meyer et al. 2003	Kimberlite
2003	Canagau property - Ben Nevis Twp.	OFR 6131	Meyer et al. 2004	VMS
2003	Gold potential in the Shining Tree area	OFR 6131	Meyer et al. 2004	Au
2003	Larder Lake–Cadillac Break west of Matachewan	OFR 6131	Meyer et al. 2004	Au
2003	Kimberlite targets northeast of Kirkland Lake	OFR 6131	Meyer et al. 2004	Kimberlite
2003	Potential for further gold discoveries in the Gauthier Group of volcanic rocks	OFR 6131	Meyer et al. 2004	Au
2004	Carbonate alteration zones in drill core stored at Kirkland Lake Remote Drill Core Site	OFR 6150	Meyer et al. 2005	Au
2004	Exploration for diamonds revisited	OFR 6150	Meyer et al. 2005	Kimberlite
2004	Milligan auriferous quartz boulders - comments and recommendations	OFR 6150	Meyer et al. 2005	Au
2004	North-trending auriferous and non-auriferous quartz veins and structures in the Kirkland Lake area	OFR 6150	Meyer et al. 2005	Au
2005	Diamond-bearing lamprophyre in the Kirkland Lake–Cobalt area	OFR 6184	Meyer et al. 2006	Kimberlite
2005	Paleoplacer gold potential in the Lorrain Formation of the Huronian Supergroup	OFR 6184	Meyer et al. 2006	Au

Year	Title	MP/OFR	Reference	Commodity
2005	Diamond exploration - west of Kirkland Lake	OFR 6184	Meyer et al. 2006	Kimberlite
2005	Kerr Mine - Gauthier Assemblage - Nettie Lake gold trend	OFR 6184	Meyer et al. 2006	Au
2006	Iron ore - renewed interest	OFR 6204	Guindon et al. 2007	Fe
2008	Gold exploration targets in the northern Burntbush area	OFR 6236	Grabowski et al. 2009	Au
2009	Gold deposits in the Blake River Assemblage	OFR 6248	Guindon et al. 2010	Au
2009	Gold structures in the Kirkland Lake District	OFR 6248	Guindon et al. 2010	Au
2010	Shining Tree - give me a break	OFR 6265	Guindon et al. 2011	Au
2011	Gold-rich VMS deposits in Ontario	OFR 6275	Guindon et al. 2012	VMS
2012	There are prospective gold areas other than along the big faults	OFR 6287	Guindon et al. 2013	Au
2013	Temagami area - a review	OFR 6295	Guindon et al. 2014	PGE, Cu, Ni
2014	Gold in the Round Lake Batholith (based on alluvium sampling)	OFR 6305	Guindon et al. 2015	Au
2015	Gold in the Round Lake Batholith - re-visited	OFR 6318	Guindon et al. 2016	Au
2015	VMS potential in the Blake River Assemblage	OFR 6318	Guindon et al. 2016	VMS
2016	Cobalt potential in the Kirkland Lake District	OFR 6328	Chadwick et al. 2017	Cobalt
2016	Data mining of surficial and deep overburden surveys in the Kirkland Lake Resident Geologist District	OFR 6328	Chadwick et al. 2017	Au
2017	Volcanogenic massive sulphide deposits in Ben Nevis Township: Are we missing something?	OFR 6340	Chadwick et al. 2018	Au (VMS)
2017	Gold – Getting back to basics	OFR 6340	Chadwick et al. 2018	Lode Au

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HIGHLIGHTS

- **Numerous small greenstone belts and volcanic outliers in the Superior Province of the Sudbury District host zinc occurrences**
- **The majority of the zinc mineralization is stratiform within the volcanic sequence and the associated sediments**
- **Vein and deformation zone hosted mineralization also occurs, possibly due to the remobilization of the primary mineralization type**

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Zinc Potential in the Superior Province, Sudbury District

The Archean Superior Province rocks in the Sudbury Resident Geologist District include small greenstone belts and outliers of volcano-sedimentary sequences, the largest being the Benny greenstone belt (BGB) north of Sudbury (Card and Innes 1981). At the time of writing, 19 zinc occurrences and prospects in the volcano-sedimentary rocks of the Superior Province in the District, have been documented—3 of which are in close proximity to each other (Table 1; Figure 1). There are an additional 6 discretionary occurrences in the area (*see* Figure 1; Ontario Geological Survey 2018a).

The principal zinc mineralization styles are volcanic-, clastic- and carbonate-hosted, and vein/replacement (Huston et al. 2005). In the volcano-sedimentary belts of the Superior Province in the District, zinc mineralization is described as stratiform (hosted by volcanic rocks or by inter-volcanic sediments), in veins and stringers, or in deformation zones (Ontario Geological Survey 2018b).

The first known work on a zinc-copper-lead-silver property was undertaken in the BGB on the Stralak prospect in Craig Township *circa* 1886 (MDI41I13SE00044). A good description of the exploration history of the Stralak property (including both east and west showings) is given by Batson (2016). The mineralization is described as stratabound, occurring in schistose siliceous graphitic rocks at the contacts between volcanic rocks, and is interpreted to be synvolcanic in origin (Batson 2016). Shear zone-hosted mineralization also occurs in the area, possibly remobilized from the primary mineralization.

The Geneva Lake Mine, located in the BGB, is suggested to be stratigraphically similar to the Stralak mineralization. Although designated as a developed mineral prospect with reserves in the Mineral Deposit Inventory (Ontario Geological Survey 2018a), the Geneva Lake Mine (Map Number 6 in Table 1 and on Figure 1) was in production from 1941–1944; producing 73,108 Tonnes (80,588 short tons) at 3.34% Pb and 9.21% Zn (Card and Innes 1981). The historical ore resource from 1951 (non-NI 43-101 compliant; *from* Shklanka 1969) is 130,419 Tonnes (114,000 short tons) at 10% Zn and 3% Pb, over an average width of 1.6 m (5.3 feet). The deposit is described as conformable to stratigraphy with crosscutting veins. Interpretation of the genesis of the deposit ranges from a replacement deposit within sediments (Osborne 1929; Shklanka 1969), a volcanogenic massive sulphide deposit (Card and Innes 1981; Sutcliffe and Tracanelli 2002) to a possible discordant vein (Sutcliffe and Tracanelli 2004).

Table 1. Zinc occurrences in the volcano-sedimentary belts of the Superior Province, Sudbury Resident Geologist District, data *from* Ontario Geological Survey 2018a.

Map Number	Occurrence Name	MDI Number	Occurrence Type	Host Rock	Status
1	Stralak Prospect West Showing	MDI41I13SW00004	Stratiform	Sheared intermediate metavolcanic rocks	Prospect
2	Stralak River East Zone	MDI41I13SE00044	Stratiform	Sheared intermediate metavolcanic rocks	Prospect
3	Turja Property	MDI41I13SE00045	Stratiform	Intermediate metavolcanics tuffs	Mineral Occurrence
4	Jerome Exploration Dublin Group	MDI41P04SE00004	Stratiform	Silicified quartz-muscovite schist associated with mafic metavolcanic tuffs; possible exhalite	Mineral Occurrence
5	Falconbridge DDH MU10	MDI41I13SE00018	Stratiform and vein	Argillite at or near contact with felsic metavolcanic tuffs; also, in fractures	Mineral Occurrence
6	Geneva Lake Mine	MDI41I13SE00002	Stratiform and vein	Sericite schist (felsic metavolcanic rocks or siliceous metasediments); lenticular-tabular body and crosscutting veins	Developed Mineral Prospect with Reserves
7	Zinc Lake Prospect	MDI41P03NW00013	Stratiform and vein	Cherty “greywacke” interbedded in chloritic schist (mafic-intermediate metavolcanic rocks)	Prospect
8	Pine Tree Trench	MDI000000000718	Stratiform	Felsic metavolcaniclastic rocks	Mineral Occurrence
9	Hudbay Mining DDH 81-3	MDI41I14NW00012	Stratiform and vein	Intermediate to felsic metavolcanic rocks; stringers	Mineral Occurrence
10	Venetian Lake Prospect	MDI41I14NW00011	Stratiform	Felsic metavolcanic tuff and chlorite schist (mafic-intermediate metavolcanic rocks); small massive lenses	Prospect
11	Copenhagen Shaft	MDI41I14SE00021	Stratiform	Iron formation in mafic metavolcanic sequence	Mineral Occurrence
12	Moose Mountain Metal Occurrence	MDI41I14SE00031	Stratiform	Cherty graphitic sediments near transition from mafic to felsic volcaniclastic rocks	Prospect
13	G. Barry Property	MDI41I14SE00032	Stratiform	Cherty sediments	Mineral Occurrence
14	T. Miron	MDI41I15SW00060	Stratiform	Felsic metavolcanic tuff	Mineral Occurrence
15	E. Rivers Property	MDI41I15SW00070	Stratiform	Intermediate to felsic metavolcanic tuffs	Mineral Occurrence
	Palston	MDI41I16SW00034	Stratiform	Cherty pebble metaconglomerate	Mineral Occurrence
16	Jerome South	MDI41I16SW00031	Stratiform	Silicified conglomerate-argillite	Mineral Occurrence
	Jerome North	MDI41I16SW00033	Stratiform	Cherty conglomerate	Mineral Occurrence
17	J. F. Grainger	MDI41I16NW00039	Stratiform	Siliceous metavolcanic breccia	Mineral Occurrence

Abbreviations: DDH, diamond-drill hole; MDI, Mineral Deposit Inventory

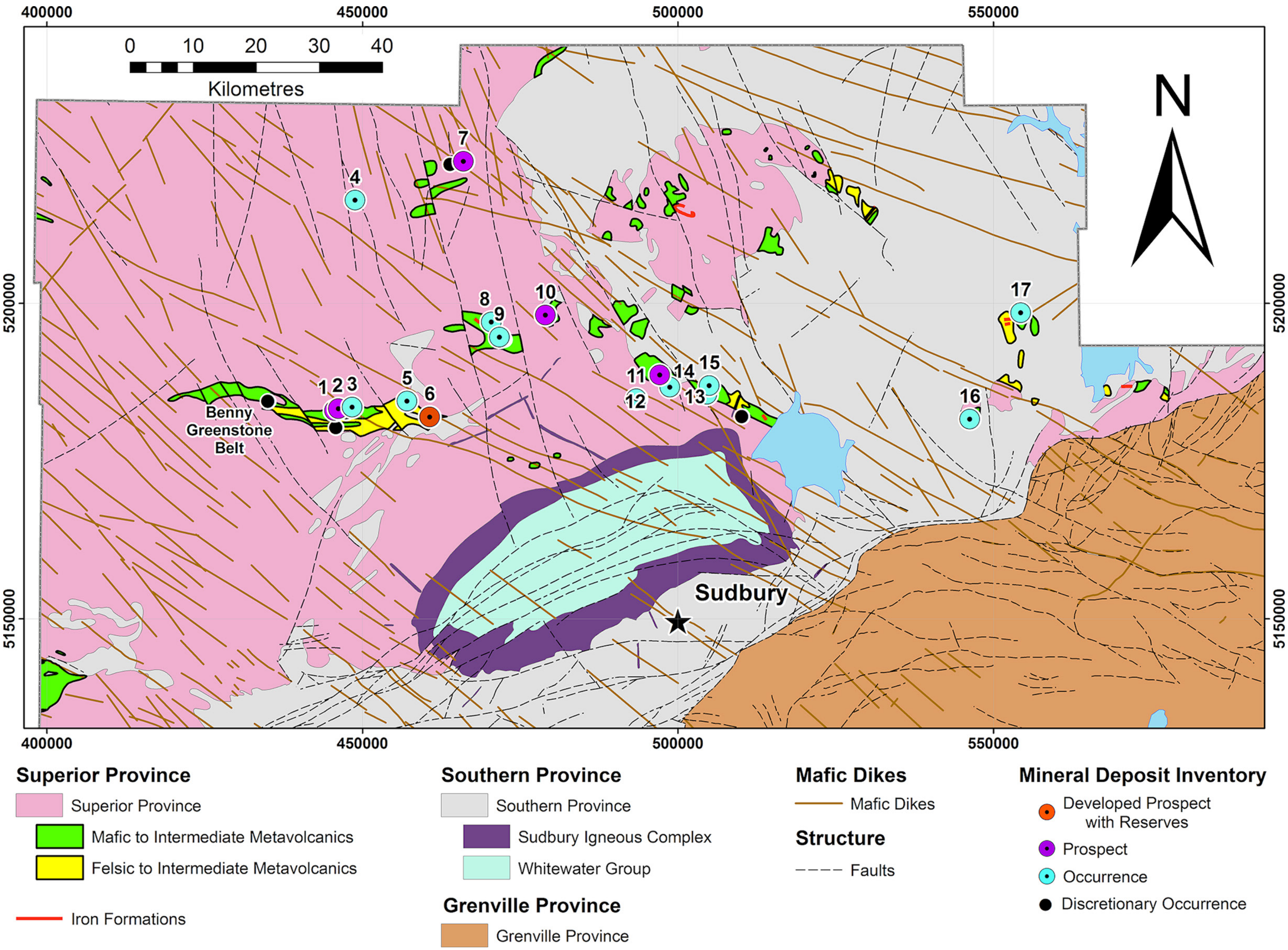

Figure 1. Map showing zinc occurrences (*see* Table 1) in the Superior and Southern provinces (data *from* Ontario Geological Survey 2018a; geology *from* Ontario Geological Survey 2011). Universal Transverse Mercator (UTM) co-ordinates are provided using North American Datum 1983 (NAD83) in zone 17.

The descriptions given in the assessment reports for the zinc occurrences in the Superior Province show that most are associated with siliceous or silicified sediments or volcano-clastic rocks in a volcanic sequence (*see* Table 1; Ontario Geological Survey 2018b). The sediments are often cherty and may be exhalative in origin. The presence of graphitic or argillitic sediments is also common in exhalative base metal deposits (Gibson et al. 2007; Figure 2a). The examples where the mineralization is associated with deformation zones may be the result of remobilization of primary volcanogenic massive sulphides (VMS), whereas the vein mineralization could be either primary veining (stockwork or stringer zones) or remobilization of primary mineralization. Sericitization and silicification are described for some occurrences and are common alterations in VMS systems (Figure 2b). In the cases here, the alteration mineral assemblages could be metamorphic in origin, or primary or secondary hydrothermal alteration.

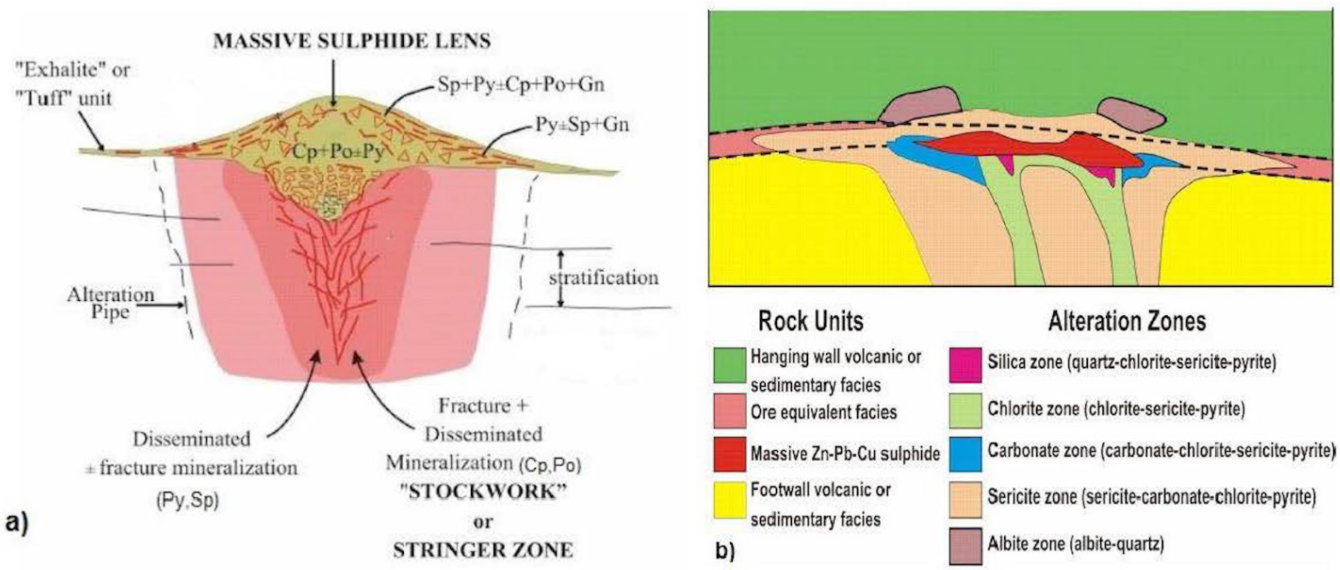

Figure 2. A. Model of a volcanogenic massive sulphide (VMS) deposit: Py = pyrite, Cp = chalcopyrite, Po = pyrrhotite, Sp = sphalerite, Gn = galena; *modified from* Gibson et al. (2007). **B.** Model footwall and hanging wall alteration associated with VMS; *from* Gibson et al. (2007).

Recommendations for Exploration

The volcano-sedimentary sequences of the Archean Superior Province in the District host several recorded zinc occurrences. Based on their descriptions (Ontario Geological Survey 2018b), many of the occurrences share characteristics with VMS deposits: conformable to semi-conformable to volcanic stratigraphy that occur within a volcanic sequence either within volcanic layers or interlayered sediments. Although some occurrences may represent VMS mineralization remobilized within deformation zones or veins, the volcano-sedimentary sequences in the Superior Province of the District also provide an opportunity to explore for primary VMS.

As VMS deposits are stratiform deposits, understanding the stratigraphy through detailed compilation and mapping should be undertaken. Compilation should include available geology, lithogeochemistry, known mineral occurrences and available geophysical surveys. Data on known mineral occurrences should be examined for possible classification as proximal or distal, and any associated alteration. In the stratigraphic compilation, attention should be given to possible exhalites or tuff beds and alteration halos that could be used to vector toward a deposit.

Information on the availability of land tenure in the Sudbury Resident Geologist District can be obtained from the Mining Land Administration System (MLAS) website (https://www.mndm.gov.on.ca/en/mines-and-minerals/land-tenure-and-geoscience-resources).

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HIGHLIGHTS

- **2018 desktop design project identifies 15 new targets for zinc exploration in southern Ontario**
- **Reopening of the Balmat Mill in NY State brings underutilized infrastructure nearby**
- **Targeted deposit types are SEDEX-MVT-VMS-silicate zinc and Zn-Pb skarn**
- **New opportunities for zinc exploration following 2 decades of dormancy**

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Zinc Prospectivity in Southern Ontario: New Exploration Targets

Preface

The recommendations and conclusions herein are based in part on the results of Brearton et al. (2018), a 4th year geological engineering design project at Queen's University developed to identify targets for zinc exploration in southern Ontario. The students were supervised by Dr. G. Olivo, Professor of Economic Geology at Queen's University in Kingston (Ontario) and the first author.

The study's recommendations were supplemented with additional insight from field work carried out during the 2018 field season by the Tweed Resident Geologist Program staff. The full report (Brearton et al. 2018) is available at the Tweed Resident Geologist office.

Introduction

Exploration for zinc in southern Ontario has been dormant since 1998.

The objective of this project was to identify target areas for zinc exploration in southern Ontario within the Composite Arc Belt (CAB) and the Frontenac Belt (FB) of the Grenville Province (Figure 1). This project used publicly available data including geological, geochemical, and geophysical survey data as well as information in the Mineral Deposit Inventory (MDI) database (Ontario Geological Survey 2018), to vector towards targets for zinc mineralization.

The parameters favorable for the presence of zinc mineralization were compiled from literature on sedimentary exhalative (SEDEX), Mississippi valley type (MVT), volcanogenic massive sulphide (VMS), skarn and silicate zinc deposits; occurrences of which all occur in the Grenville Province.

There are several known zinc deposits in the study area and in neighbouring jurisdictions (Figure 1). The deposits include the Deer Lake, Calumet (Quebec) and Simon deposits, believed to be of VMS origin; and the Cadieux (1.45 Mt at 8.8% Zn and 0.8% Pb, non-NI 43-101 compliant), Salerno Lake (797,000 tonnes at 6.3% Zn, non-NI 43-101 compliant), and Long Lake past producing mine (94,631 short tons at 11.6% Zn; 1974–76), thought to be of SEDEX origin. The world class Balmat–Edwards zinc mining district in the Adirondack Belt of northern New York State (USA) is located less than 35 km from the southeast border of Ontario. The district has been in operation since 1903. Past production and reserves contained 45 million tonnes at an average grade of 9.4% Zn (Whelan, Rye and deLorraine 1984). Empire State Mines reopened the Balmat–Edwards mines and mill in 2017. A number of smaller yet significant zinc occurrences also occur in the study area such as the Spry, Cook, Ardock, Pharaoh, 30 Island Lake, Northgate B, Slave Lake and Wilkinson which are carbonate-hosted stratiform or stratabound occurrences and the Mazinaw, International, Kashawakamak, Grandad and James polymetallic occurrences (Zn, Pb, Cu, Ag, ±Au) that are individually of a hydrothermal cross- cutting nature (vein-filling) but collectively are stratabound (i.e., occurring at the same stratigraphic level).

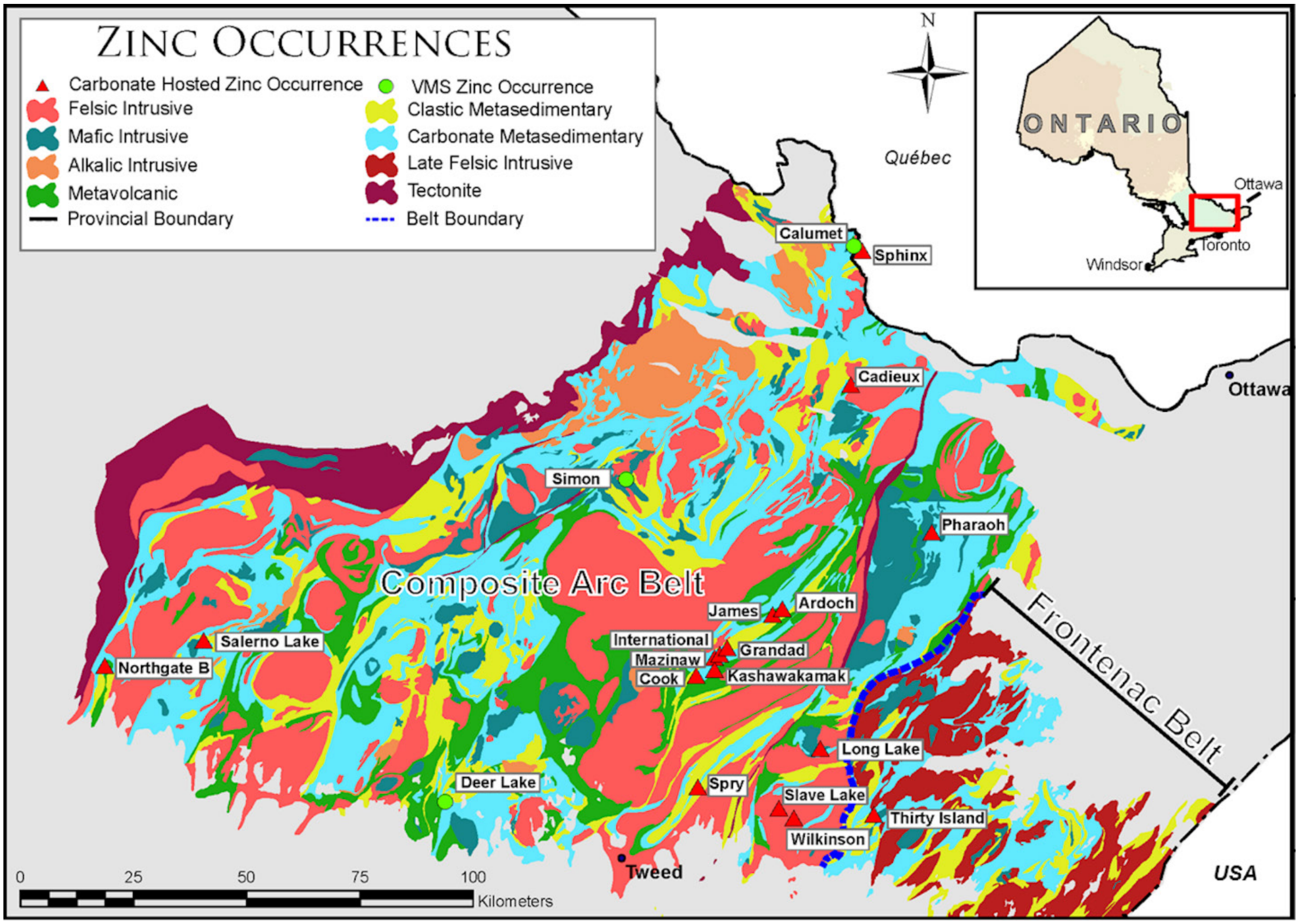

Figure 1. Geological map showing the Composite Arc Belt and Frontenac Belt of the Grenville Province (geology *from* Ontario Geological Survey 2011) and the location of zinc deposits and occurrences (data *from* Ontario Geological Survey 2018). Note that Calumet and Sphinx are 14 km north of the Quebec–Ontario border.

Methodology

Publicly available geochemical data from the Ontario Geological Survey (OGS) and the Geological Survey of Canada (GSC) was incorporated in the study and included analyses of lithogeochemistry, lake and stream sediments, and lake and groundwater geochemistry. Concentrations of deposit-specific pathfinder elements were compared on a magnitude basis to determine anomalous concentrations which may be indicative of zinc mineralization. These elements included Zn, Pb, Cu, Co, Cd, As, Au, Ag, Mn, Fe, Ba, Be, and S.

Magnetic, gravimetric, electromagnetic, and radiometric geophysical surveys were all considered for the project. Magnetic and gravimetric surveys were deemed most effective to compare known zinc prospects with potential mineralization targets because of their wide coverage and spatial resolution. These geophysical methods were also employed to identify the geological framework necessary for target identification.

A raster analysis was conducted for the aforementioned geochemical and geophysical data to identify common anomalies between data sets that were favourable for zinc mineralization. Each data set considered for the raster analysis was weighted depending on its favourability for zinc mineralization and was then combined into a single cumulative raster in the form of a heat map. Raster heat maps were then produced for each sought after deposit type identifying target areas (Figure 2).

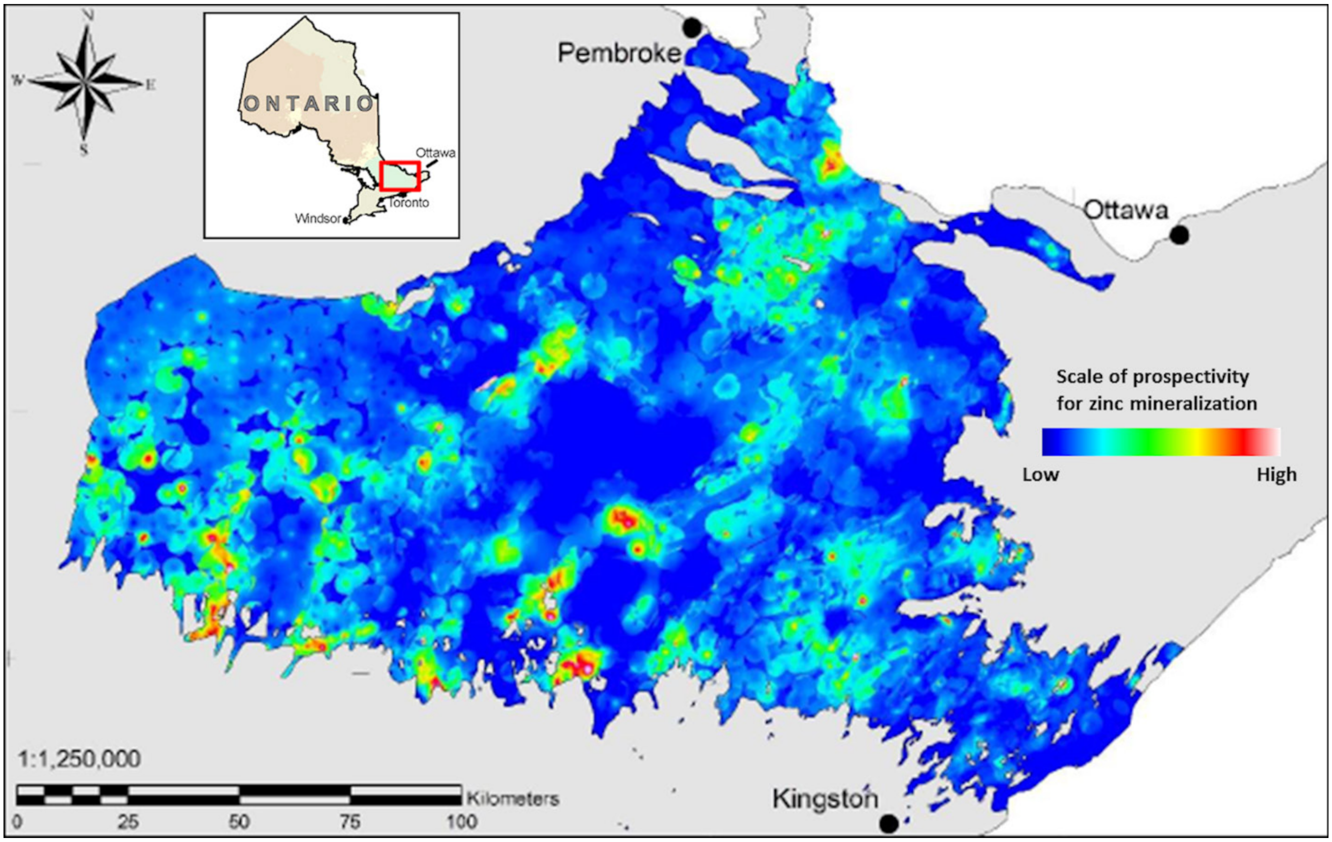

Figure 2. Example of a cumulative raster heat map using exploration parameters for SEDEX-type zinc deposits for southern Ontario. Similar heat maps were also produced for MVT-VMS-silicate Zn and Zn-Pb skarn deposit-types (*from* Brearton et al. 2018).

Once the targets were identified, a geological investigation at the local scale was carried-out using data from geological maps and reports published by the OGS. These maps were used to ensure geological validity for any given target identified by the raster analysis and at this stage of the study, many targets were eliminated based on the geology where the anomaly occurred. Information from the MDI database (Ontario Geological Survey 2018) was used to validate the raster analysis method in areas of known zinc deposits, providing insight about local mineralization in the assessment of each target.

Results

It came as no surprise that cumulative raster heat maps generated for the different deposit types outlined similar target areas. For example, the presence of zinc and lead are top indicators of all genetic types of zinc mineralization and appear on the heat map for all deposit types.

The cumulative raster analysis proved successful at identifying several areas of known zinc mineralization such as the Cadieux deposit and the Northgate B, Deer Lake, Simon, Spry, 30 Island Lake, Ardoch and Pharaoh occurrences. These areas are considered as excellent targets.

Several noteworthy zinc deposits and prospects that were not identified as targets by the cumulative raster analysis include the Long Lake past producer, the Salerno Lake deposit and the Cook, Slave and Wilkinson occurrences. A lack of geochemical data in the Salerno Lake area may account for why the Salerno Lake deposit was not identified as a target. The Long Lake past producer, the Slave occurrence and the Wilkinson occurrences all occur in small xenoliths of marble within larger intrusive bodies that may have masked their geophysical and perhaps their geochemical signature. It is unclear why the Cook occurrence was not specifically outlined; however, the northeast part of the marble belt that hosts the Cook occurrence was identified as a target by the raster analysis (specifically the Ardoch area).

A total of forty targets were initially selected using the cumulative raster heat maps. Nine of the most favourable targets were then selected based on a preliminary assessment which examined the cumulative raster values, geological setting attributes and known mineral occurrences (Figure 3 and Table 1). Eight additional medium priority areas were outlined (*see* Figure 3) and several more targets were downgraded to lower priority targets mostly due to their potential social and environmental challenges.

Preliminary Economic Study

A preliminary economic study for zinc deposits in southern Ontario was also carried out during this project (Brearton et al. 2018). The objective of the study was to define a target size that can be economically mined in southern Ontario. The recent re-opening of the Empire State Mine (Balmat District New York State, USA) has considerably changed the economics of such a proposition since deposits no longer must be “stand-alone” operations. The mill operated at Balmat has a capacity of 5000 t/day and is currently underutilized. It should be noted that the zinc mineralization of the Long Lake zinc mine was milled at Balmat in 1974–76 after a pre-concentration to approximately 20% Zn (Wolff 2005).

A financial model was generated using the Empire State Mine in the Balmat–Edwards district of northern New York State as an analogue. The model predicts that deposits smaller than 700,000 tonnes would not require a mill, with the ore being transported to the Empire State Mill for processing. In this case, the distance to Empire State Mine and the grade of the ore are significant factors in operating costs to consider for the success of the project (Figure 4).

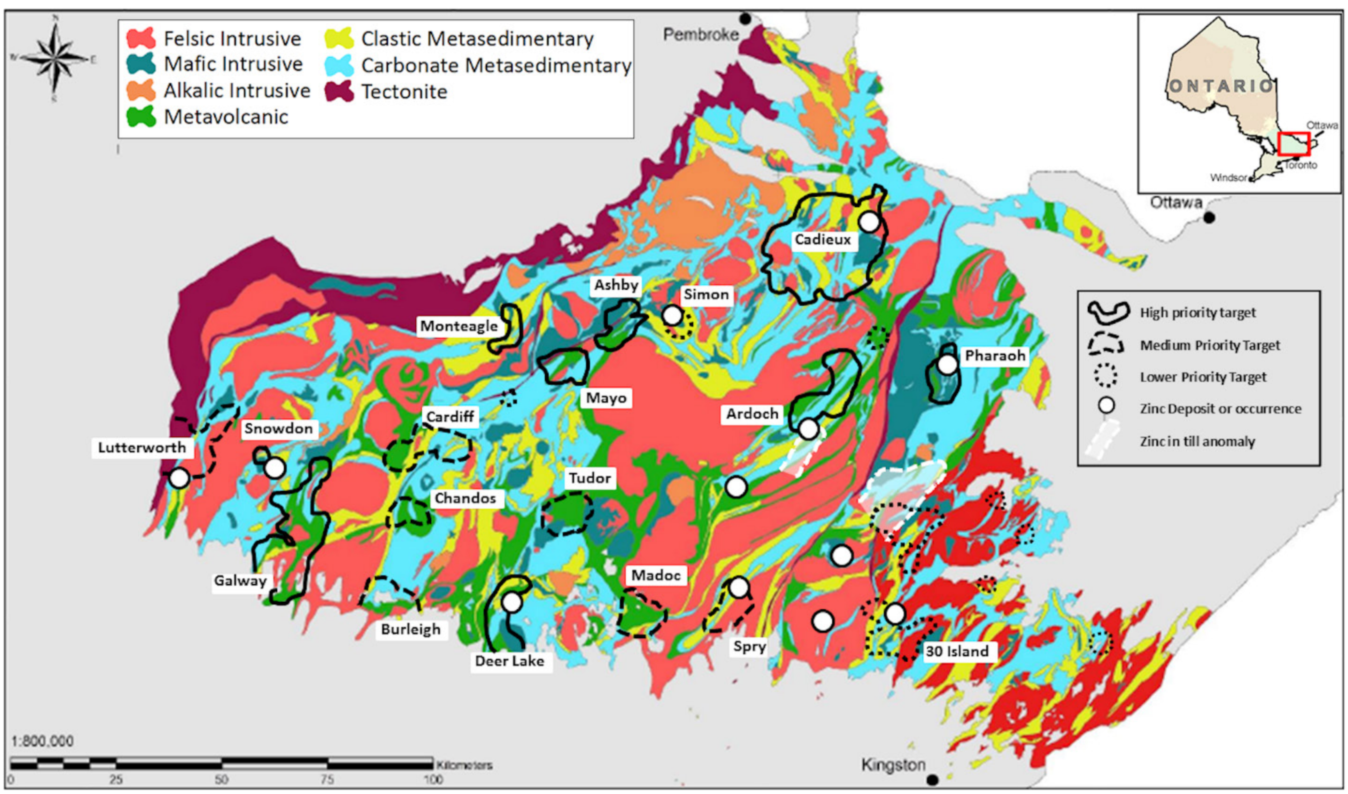

Figure 3. Geological map of the Composite Arc Belt and Frontenac Belt (Grenville Province) showing the target areas defined by the cumulative raster analysis of this project. Zinc in till data *from* Kettles and Shilts (1996).

Table 1. List of high priority targets defined by the cumulative raster analysis. Known mineralization data *from* Ontario Geological Survey (2018).

Target	Townships	Area (approximate)	Dominant Lithologies	Known Zinc Mineralization	TargetType
Cadieux	Admaston Brougham Gratton	20 km x 20 km	Marbles and clastic metasedimentary rocks intruded by granitoids and gabbros	Cadieux Deposit 1.45 Mt @ 8.8% Zn and 0.8% Pb	SEDEX-MVT
Pharaoh	Lanark Dalhousie	12 km x 6 km	Marbles intruded to the west by the Lavant gabbro	Pharaoh Prospect (7.1% Zn in boulder) (up to 3.96% Zn/1.5 m drill hole)	SEDEX-MVT
Ardoch	Clarendon Palmerston South Canonto	18 km x 5 km	Tightly folded marbles with clastic metasedimentary rocks and mafic metavolcanic rocks	Ardoch Occurrence (2.60% Zn/2.28 m in drill hole) (Zn anomaly in till to south)	SEDEX-MVT (-VMS?)
Ashby	Ashby Raglan	10 km x 5 km	Folded mafic to felsic metavolcanic rocks with marbles	None known	VMS-SEDEX-MVT
Mayo	Mayo	7 km x 7 km	Folded mafic to felsic metavolcanic rocks with marbles	None known	VMS-Zn-Pb Skarn
Monteagle	Monteagle	8 km x 2 km	Marbles, granitoids and minor clastic amphibole-rich metasedimentary rocks	None known	Zn-Pb Skarn
Snowdon	Snowdon	2 km x 2 km	Marbles and clastic metasedimentary rocks	None known but proximal to Salerno deposit (797,000 t @ 6.3% Zn)	SEDEX-MVT
Deer Lake	Belmont Marmora	15 km x 5 km	Marbles, clastic metasedimentary rocks and mafic metavolcanic rocks	Deer Lake Deposit (0.1 to 1.13% Zn in drill hole)	VMS-SEDEX-MVT
Galway	Harvey Galway Cavendish	28 km x 7 km	Metavolcanic belt with minor marbles and clastic metasedimentary rocks nintruded by granitoids	None known except a few minor occurrences (Zn in till anomaly)	VMS-SEDEX-MVT

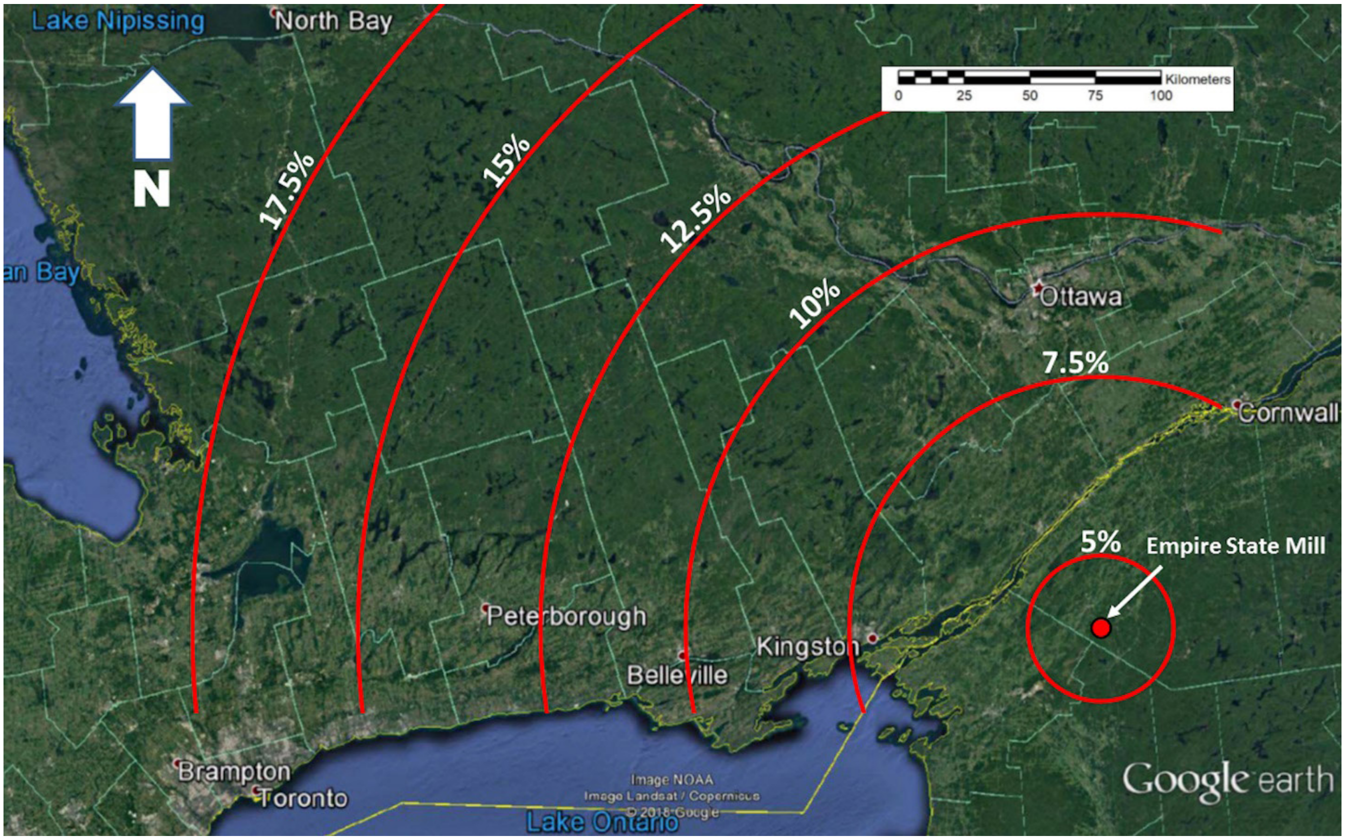

Figure 4. Contour map showing the minimum grade required for a 500,000 t deposit without a mill to be economic when shipping ore to Empire State Mine's mill in New York State, USA (modified from Brearton et al. 2018).

Conclusion

With the world class Balmat–Edwards Mine (45MT of 9.4% Zn) situated in the Grenville Province of NY State, less that 35 km from the Ontario border, the potential for zinc mineralization in the Grenville Belt of southern Ontario is undeniable. Furthermore, the reopening of the Balmat Mine and mill by Empire State Mines in 2017 provides infrastructure to the area that favourably changes the economic parameters needed to bring a mine into production in southern Ontario.

The raster analysis approach presented herein for zinc exploration in the CAB and FB of southern Ontario was successful at identifying most of the existing zinc deposits and occurrences in the area. The method also identified 40 new areas of interest for zinc exploration. Following validation and prioritization, a total of 9 targets were selected as highly favourable, *see* Table 1 and Figure 3. These new targets are even more exciting since there has been no exploration for zinc in southern Ontario over the last 2 decades.

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HIGHLIGHTS

- **Demand is increasing for high-purity, high-brightness carbonate mineral fillers for the paper, paint and plastics industries**
- **Southeastern Ontario has current production and significant past production of high-purity calcite and dolomite marbles for industrial mineral use**
- **Recent geological mapping by the Ontario Geological Survey had identified new areas with good potential for locating deposits of high-purity marbles**

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High-Purity Marble Deposits, SE Ontario: Industrial Mineral Potential

Introduction and Market Outlook

Marble belts of the Central Metasedimentary Belt (CMB) of the Grenville Province in southeastern Ontario (Figure 1) contain deposits of high-purity calcitic and dolomitic marble which are currently quarried as sources of mineral filler for the paint, paper, plastics and pharmaceutical industries and for terrazzo, decorative stone and landscaping stone.

Precipitated calcium carbonate (PCC) and ground calcium carbonate (GCC) are used primarily as filler and extender material in the paper, paint and plastics industries but are also important in construction (drywall and joint compounds), adhesives, rubber, food, pharmaceuticals and animal feedstock. In North America, the GCC segment held the largest market share in 2017, accounting for nearly 81% of the calcium carbonate market. The calcium carbonate market in North America is projected to grow at a compound annual growth rate (CAGR) of close to 5% from 2018 to 2022 (https://www.businesswire.com/news/home/20180421005042/en/Calcium-Carbonate-Market-North-America---Market).

White marble deposits are the most abundant sources of high-purity, high-brightness carbonate, providing additional physical properties such as stiffness, color, and opacity. Brightness, particle size, and chemical purity are the properties of carbonate fillers that are crucial in industrial uses.

High-purity, high-brightness dolomitic marble can substitute as a less costly alternative to calcitic marble in some applications, such as joint compounds, vinyl floor tiles, grouts, exterior plasters and stucco, asphalt roofing, and cast polymers (manufactured marble tiles and countertops).

The key points identified in a recent study of the global calcium carbonate market are the following for the forecast period from 2017 to 2025: (https://www.grandviewresearch.com/press-release/global-calcium-carbonate-market)

- The global calcium carbonate demand is expected to reach 180.1 million tons by 2025 (from 113.7 million tons in 2016) at an estimated CAGR of 5.3% from 2017 to 2025.
- Approximately 50% of the global calcium carbonate demand in 2016 was accounted for by the paper industry and is expected to continue as the leading market over the forecast period.
- The paints and coatings segment is expected to register a CAGR of 5.9% in terms of revenue over the forecast period.
- Reducing resin content permits significant cost savings on raw materials by replacing about 40% of plastic with calcium carbonate.

Southern Ontario Production and Prospects

Locations of producers, significant prospects, and known occurrences of high-purity calcitic and dolomitic marble are shown in Figure 1. The locations of occurrences shown in Figure 1 were obtained from a search of the Ontario Geological Survey's Mineral Deposits Inventory (MDI) database for "high-purity marble" (Ontario Geological Survey 2018).

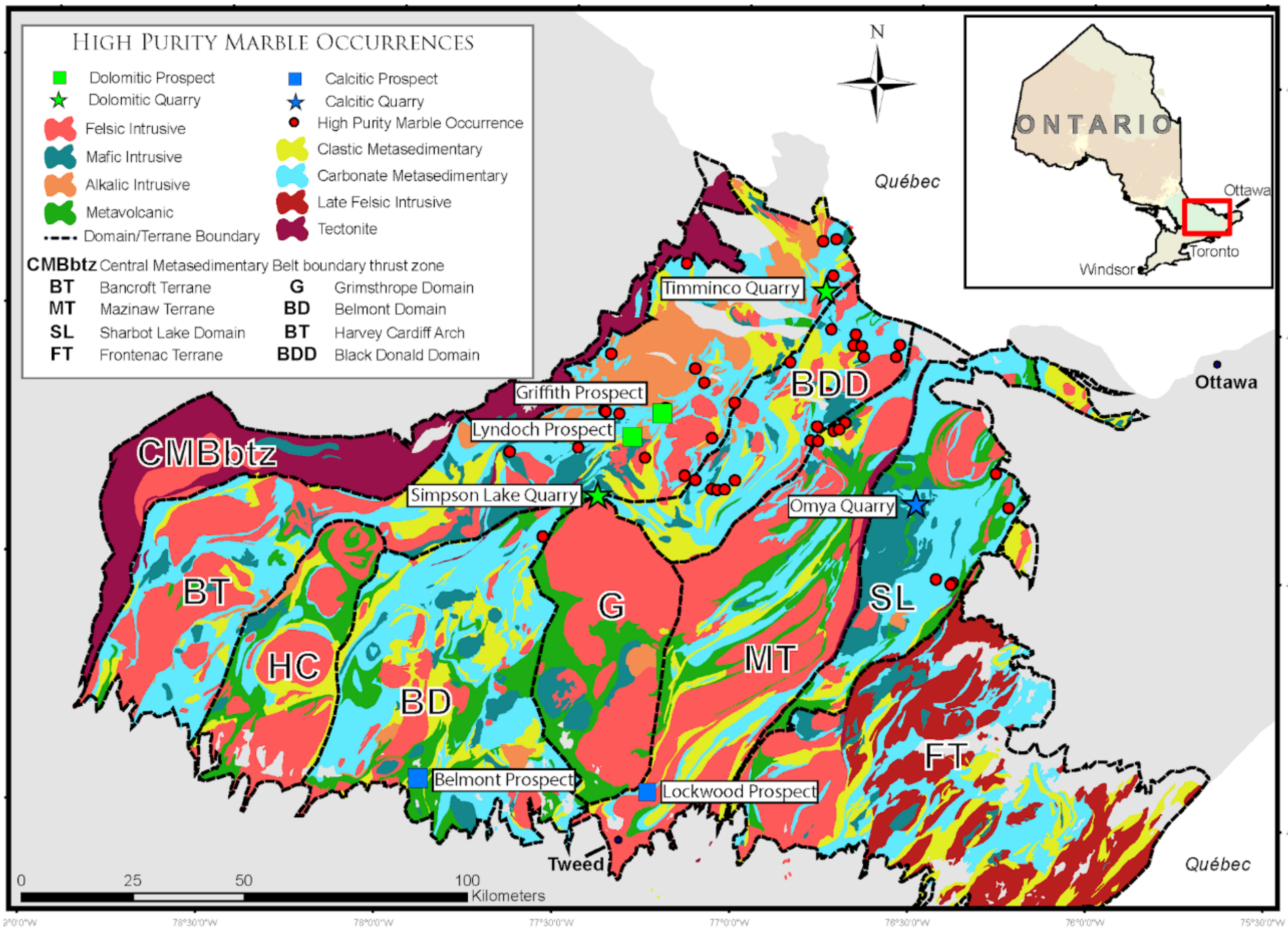

Figure 1. Geology of the Central Metasedimentary Belt (major marble belts shown in pale blue) and locations of high-purity marble quarries, prospects, and occurrences, southeastern Ontario; geology *from* Ontario Geological Survey (2011).

The only current producer of GCC from southern Ontario marble is OMYA Canada Inc. White, calcitic marble is extracted from a high-purity zone about 85 m wide at the company's Tatlock Quarry in Darling Township and trucked to the company's processing plant at Perth. In high-demand years, the company quarries about 650,000 tonnes from the deposit, which is estimated to contain an additional 5 million tonnes of reserves. Various grades and sizes of dry ground and slurry calcium carbonate are produced for use in the paper, paint and plastics industries.

High-purity dolomitic marble was quarried for magnesium metal production in Ross Township at Haley Station near Renfrew. The deposit consisted of a 75 m wide zone of coarsely crystalline dolomite containing less than 1% impurities (chondrodite, talc, tourmaline and tremolite) and was quarried over a strike length of over 700 m (LeBaron and MacKinnon 1990). The quarry and plant were operated originally by Dominion Magnesium Limited and later by Timminco Metals for a total of 63 years before ceasing production in 2007.

Two other properties in southeastern Ontario host significant drill-indicated reserves (not NI 43-101 compliant) of high-purity marble. The Whitney Calcite property in Belmont Township, explored by Preussag Canada Ltd. and Northumberland Mines Ltd. between 1975 and 1980, contains 1.9 million tonnes of high-calcium marble and 4.7 million tonnes of calcitic/dolomitic marble, both zones containing less than 0.5% SiO_2 + Fe_2O_3 and averaging 93% brightness (LeBaron and MacKinnon 1990). The Lockwood Property in Elzevir Township, diamond drilled by Omya in 1974, is estimated to contain 3 million tonnes of white, high-calcium marble averaging less than 2% acid insoluble content. The footwall of the calcitic zone is a 50 m thick dolomitic zone, visually estimated to contain less than 3% impurities (LeBaron and MacKinnon 1990).

Areas Recommended for Exploration

Although there is potential for the discovery of high-purity marble in all marble belts of southeastern Ontario, the following areas are recommended for exploration:

LANARK–DARLING–RAMSAY TOWNSHIPS

This wide marble belt contains several occurrences of high-purity carbonate and hosts the Omya deposit at Tatlock. Mapping in the Perth and Carleton Place areas by Easton (2015, 2016, 2018) identified abundant clean, high-brightness, low silica content, calcitic and dolomitic marbles of the Sharbot Lake Domain (*see* Figure 1) as having industrial mineral potential. Major oxide content of samples reported by Easton (2015, 2018) are listed in Table 1.

LYNDOCH–GRIFFITH–BROUGHAM TOWNSHIPS

This belt of interlayered calcitic and dolomitic marbles within the Bancroft Terrane contains zones of high purity and brightness (LeBaron and MacKinnon 1990). White, dolomitic marble is quarried at Simpson Lake in Ashby Township (*see* Figure 1) and shipped to the Coloured Aggregates Inc. plant in Marmora for production of specialty aggregates for the construction industry.

Exploration work since 2014 has identified high-purity white dolomitic marble in Lyndoch Township (Lyndoch prospect, *see* Figure 1; Forget 2014). The analytical results of 2 white, dolomitic marble samples (ML-18 and ML-21) taken about 800 m apart along strike at the Lyndoch prospect are listed in Table 1. Similar results were reported by LeBaron and MacKinnon (1990) from coarse-grained, white dolomitic marble from the Griffith prospect (*see* Figure 1, Photo 1).

ROSS–HORTON TOWNSHIPS

Several marble prospects and past producers are located in Ross and Horton townships. According to Easton (2013), the area east of the Ross Fault, a north-south fault that marks a major change in bedrock geology and magnetic trends, represents a down-dropped block that preserves calcitic and dolomitic marbles of lower metamorphic grade than is typical in this part of the Central Metasedimentary Belt. These relatively high-purity marbles are the result of deposition in a carbonate basin with a low influx of siliciclastic and volcaniclastic material.

BELMONT–MADOC–HUNGERFORD–ELZEVIR TOWNSHIPS

Several occurrences exhibit adjacent zones of high-purity calcitic and dolomitic marble in the Belmont domain, an area of relatively low-grade metamorphism (LeBaron and MacKinnon 1990). High-purity prospects such as the Belmont (*see* Figure 1) indicate that there are localized zones with potential for industrial mineral development.

In addition to the potential for specialty products from high-purity marbles, lower grades of both calcitic and dolomitic marble have potential applications as terrazzo, decorative aggregate, dimension stone and lower-specification mineral fillers.

The geology and geochemistry of Grenville marble belts and specific prospects are documented in the following Ontario Geological Survey reports:

- Industrial Minerals of the Pembroke–Renfrew Area, Part 1: Marble (Storey and Vos 1981).
- Geochemistry of Grenville Marble in Southeastern Ontario (Grant, Papertzian and Kingston 1989).
- Precambrian Dolomite Resources in Southeastern Ontario (LeBaron and MacKinnon 1990).
- High-Purity Calcite and Dolomite Resources of Ontario (Kelly 1996).

Photo 1. Stripped outcrop area of high-purity, white, dolomitic marble, Griffith prospect; inset shows uniform, coarse grain size; photos by P. LeBaron 2016.

Table 1. Major oxide geochemistry of selected high-purity marble samples from southeastern Ontario; all UTM co-ordinates in NAD 83, zone 18; all results in weight %.

Sample Number	15RME-0099	15RME-0104	17RME-0093	18RME-0048	18RME-0049	18RME-0134	ML-18	ML-21
Easting (m)	390814	390376	387011	403327	403266	400528	317805	319173
Northing (m)	4983444	4983029	4984174	5000135	5000202	5007834	5015362	5015789
Rock Name	Dolomite Marble	Calcite Marble	Dolomite Marble	Dolomitic Calcite Marble	Dolomite Marble	Dolomitic Calcite Marble	Dolomite Marble	Dolomite Marble
SiO_2	0.18	0.40	0.23	0.65	0.39	0.85	0.70	0.33
TiO_2	0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.003	0.001

Sample Number	15RME-0099	15RME-0104	17RME-0093	18RME-0048	18RME-0049	18RME-0134	ML-18	ML-21
Al_2O_3	0.16	0.12	0.06	0.11	0.17	0.24	0.06	0.05
Fe_2O_3 tot	0.20	0.12	0.10	0.07	0.15	0.16	0.08	0.33
MnO	0.020	0.003	0.025	0.003	0.051	0.017	0.056	0.034
MgO	21.02	4.64	20.67	3.11	19.50	3.81	22.05	21.25
CaO	30.39	51.10	29.71	51.02	31.50	50.82	31.32	31.92
Na_2O	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.01	0.01
K_2O	0.03	0.05	0.01	0.02	0.01	0.06	0.02	<0.01
P_2O_5	0.01	0.010	0.018	0.004	<0.002	0.011	0.01	<0.01
CO_2	46.07	42.57	45.44	43.97	45.92	43.78	N/A	N/A
S	N/A	N/A	0.004	<0.003	<0.001	<0.003	N/A	N/A
LOI	47.42	44.40	47.39	43.98	47.11	44.10	44.82	46.83
Total	99.44	100.86	98.15	98.98	98.84	100.07	99.13	100.80
CaO/MgO	1.45	11.0	1.4	16.4	1.6	13.3	N/A	N/A
Reference	(Easton 2015)		(Easton 2018)				(Forget 2014)	

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Notes

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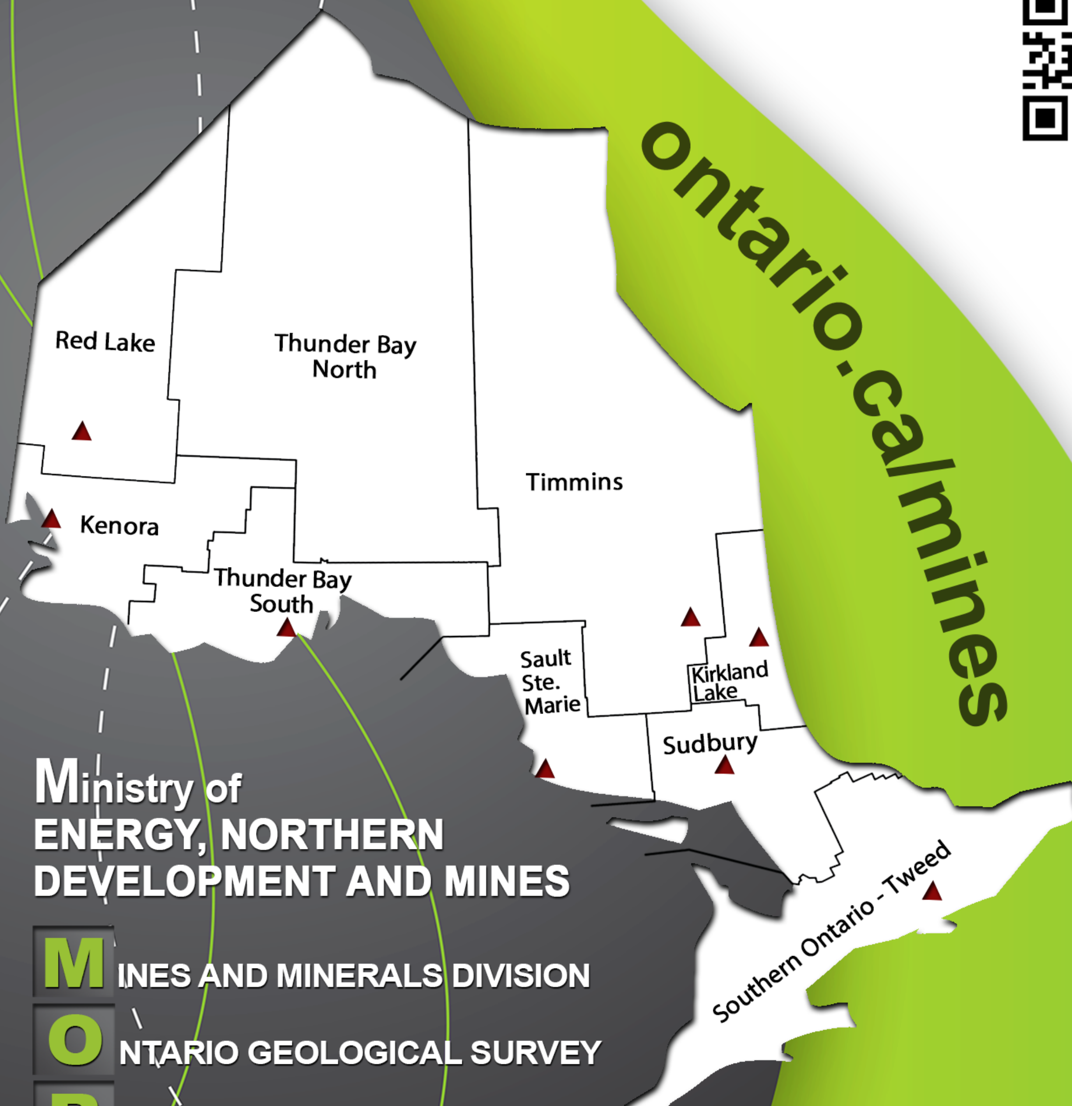

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