RECOMMENDATIONS for Exploration

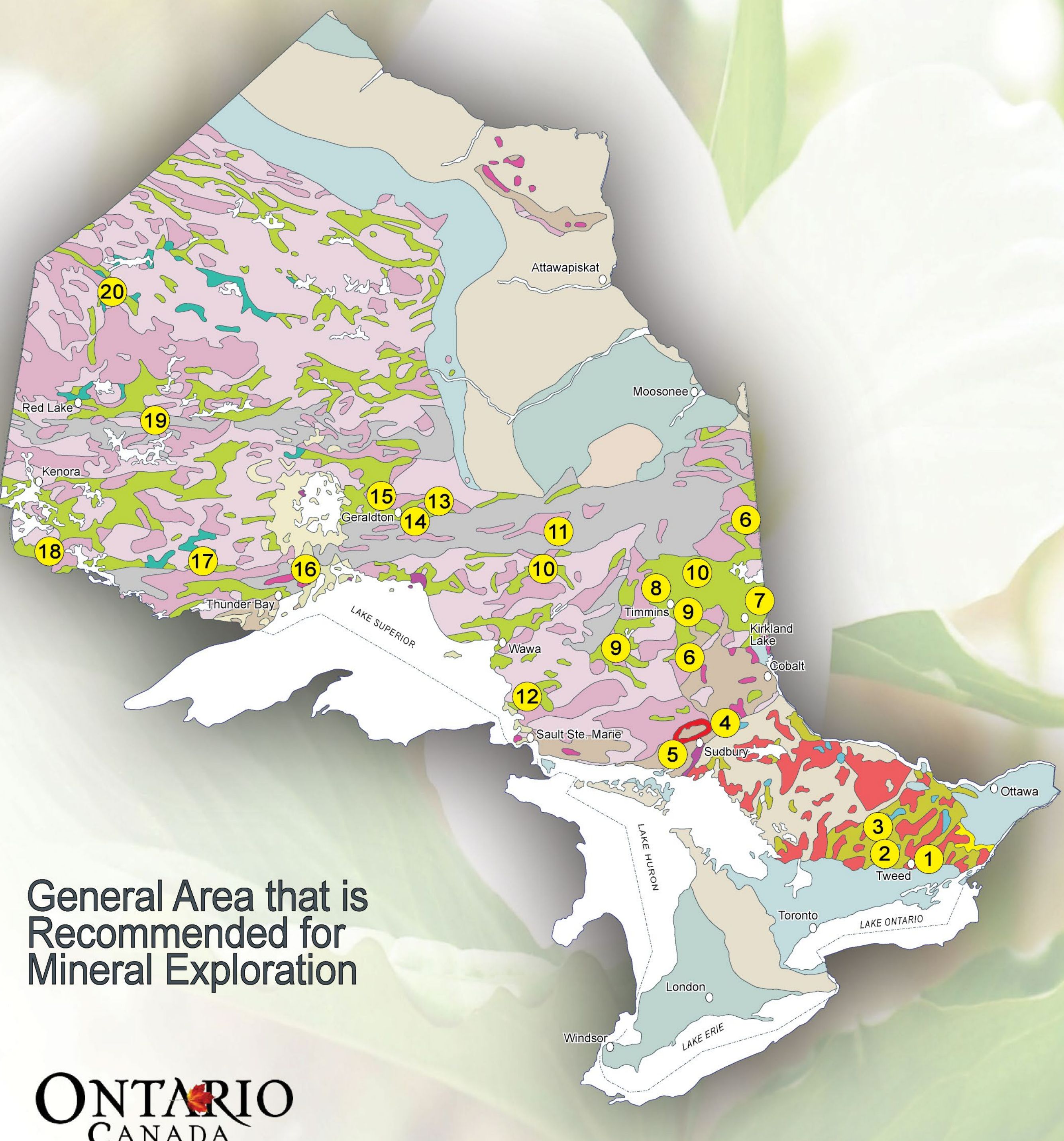
2017 - 2018

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

ONTARIO CANADA

Recommendations for Exploration

2017-2018



General Area that is Recommended for Mineral Exploration

ONTARIO
CANADA

Photo courtesy of Karen Labonte

Ontario Geological Survey
Resident Geologist Program
Recommendations for Exploration 2017–2018

The Ontario Geological Survey is pleased to issue its 2018 Recommendations for Exploration. These recommendations are the product of the Ministry's 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 MNDM Mines and Minerals Division Web site (http://www.mndm.gov.on.ca/en/mines-and-minerals/applications/ogsearth) to see what else is available.

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About the Resident Geologist Program

Resident Geologist Program staff 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.

Contents

Suma-Momoh, J. 2018. Volcanogenic massive sulphide deposits in Ben Nevis Township: Are we missing something?; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2017–2018, p.34-38.

Explore Southern Ontario with the Tweed Drill-Core Library

HIGHLIGHTS

- **Tweed Drill-Core Library is the only public repository of drill core intersecting the Precambrian rocks of southern Ontario.**
- **New exploration opportunities await discovery through re-sampling and/or re-logging historic drill core.**
- **The Resident Geologist Program administers 9 other drill-core libraries throughout the province.**

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INTRODUCTION

The Southern Ontario Resident Geologist's Office maintains a diamond-drill core library storage facility in Tweed, Ontario, one of 9 drill-core libraries (DCL) administered by the Resident Geologist Program across the province. The site houses over 250 000 m of core from 3420 drill holes in southern Ontario. The Tweed DCL is the only public repository of drill core intersecting the Precambrian rocks of southern Ontario, and a very large proportion of the core is deemed irreplaceable. Fifty-seven (57) of these drill holes start in Paleozoic sedimentary rocks and continue into the Precambrian basement rocks. The majority of core in the library was donated over the past 30 years by mineral exploration companies and mines.

Drill core can be used as an effective tool to identify potential mineral exploration targets. The Tweed DCL contains core from many areas of the Grenville Province's Central Metasedimentary Belt considered favourable for gold, base metal, rare earth and industrial mineral mineralization (Figure 1). By visiting the DCL and viewing core from these areas, one could essentially "explore" large areas of southern Ontario quickly and inexpensively using primary data. Exploration projects that include the sampling and/or re-logging of core from the Tweed DCL can submit the work completed for assessment credit.

VIEWING AND SAMPLING OUR CORE

Viewing and sampling core from previous drilling projects provides an opportunity to reassess the mineral potential of an area, including looking for commodities different from what may have been the original intent of the exploration. For example, diamond-drill core that targeted the deep parts of the talc ore body at the Canada Talc Mine in Madoc in 1987 intersected a marble unit hundreds of metres thick. Some of the marble is unfractured over good lengths of core and displays interesting textures and colours. This marble should be examined as a source of dimension stone, landscaping stone and/or decorative aggregate (Photos 1 and 2).

Other examples demonstrating this concept and the potential exploration opportunity that is present when revisiting drill core include 1) many uranium prospects, which have potential for rare earth elements (REE), and 2) some magnetite skarns drilled for iron, which also have potential for light REEs (Sangster et al. 2012). The Tweed DCL stores core from hundreds of drill holes in the historic Bancroft uranium camp and many former magnetite mines and exploration projects. Very little of this core has been analyzed for REE content.

Explore Southern Ontario with the Tweed Drill-Core Library

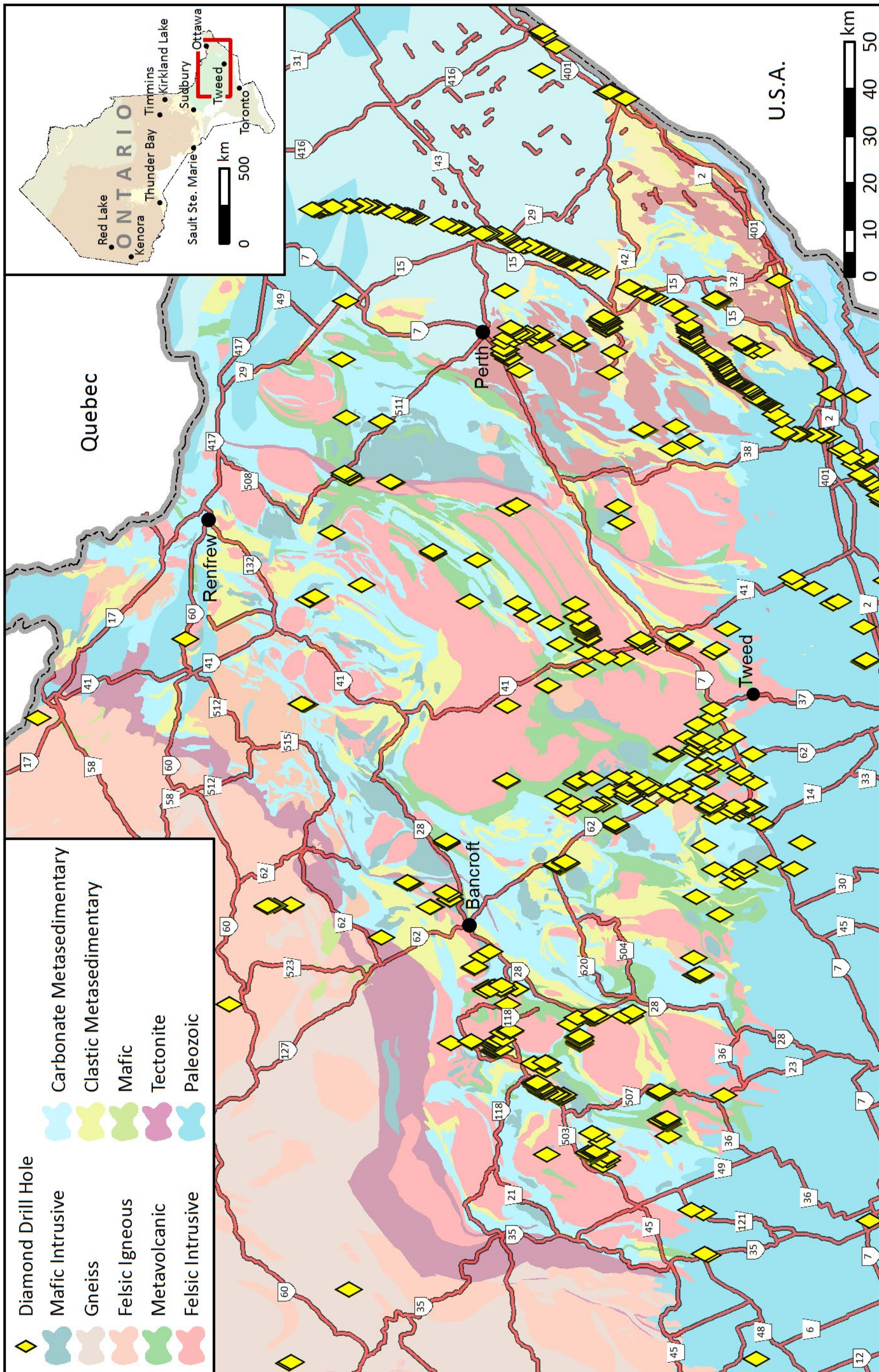

Figure 1. A generalized map of the Central Metasedimentary Belt of the Grenville Province, showing the locations of drill holes stored at the Tweed Drill-Core Library. Regional geology *from* Ontario Geological Survey (2011).

Explore Southern Ontario with the Tweed Drill-Core Library

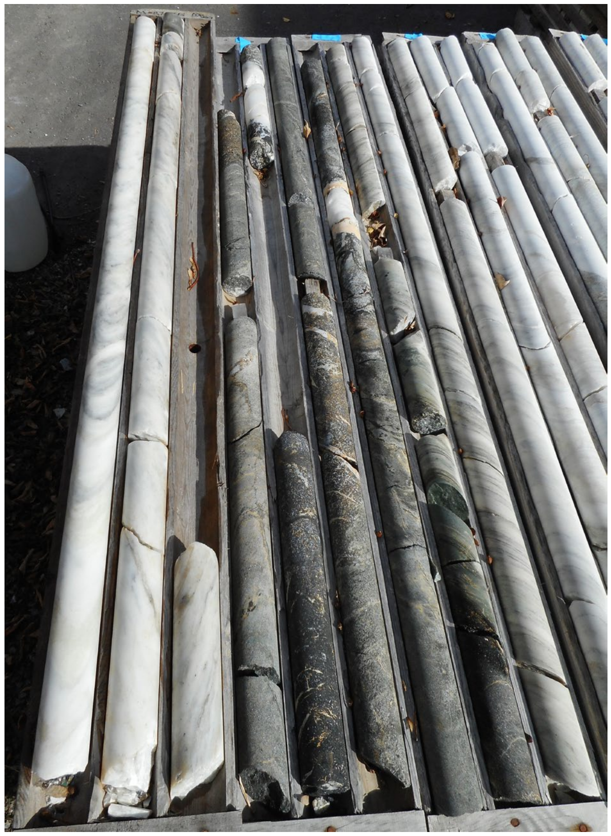

Photo 1. Banded white and pale green marble (and mafic dike), Canada Talc Mine; the piece of drill core on the extreme left of the photo is unbroken for a length of 1.5 m.

Photo 2. White marble breccia fragments with dark green serpentine matrix and veining, Canada Talc Mine.

Explore Southern Ontario with the Tweed Drill-Core Library

SUCCESS STORIES

The Tweed DCL played an important role in the development of several recent exploration projects in southern Ontario.

By example, in 2013, Union Glory Gold Limited re-logged and resampled drill core from 4 historic drilling programs completed at the Addington gold mine in the 1980s. The company took a total of 267 samples from 39 drill holes held in the DCL in order to confirm previous estimates of tonnage and grade and to upgrade the existing database to National Instrument (NI) 43-101 compliancy (McBride 2013). The resampling program was successful in advancing the project at a very low cost.

Also in 2013, as part of their Bannockburn Project, Crown William Mining Corp. collected 446 samples from 22 drill holes with the purpose of identifying low- or moderate-grade vein and wallrock mineralization that may have been missed during historic drilling campaigns. This was done to assess the potential for a high-tonnage, lower grade deposit amenable to bulk-mining methods. The resampling program was successful in identifying a zone of increased vein density and coincident wallrock mineralization, which is reported to be amenable to open pit mining (Fingas 2013).

Both resampling programs were successful in advancing the projects at a very low cost, relative to the expense of new diamond drilling.

SUMMARY

Diamond-drill core stored in the Tweed DCL is a useful resource for conducting mineral exploration. This is especially the case in southern Ontario, where assembling a land position may be more time consuming. Large areas may be explored quickly and inexpensively using primary data (i.e., the core). New exploration concepts and the potential for alternative commodities may be tested through the re-examination of historic drill core originally drilled for another purpose. Expenses related to the sampling and/or re-logging of historic drill core may be submitted for assessment credit. There is no cost to use the library and the Tweed Resident Geologist's Office is able to provide additional equipment for use, such as magnetic susceptibility meters, microscopes and core saws. Please contact the Tweed Resident Geologist Office for more information or to obtain a copy of the drill-core library catalog and a detailed map showing the locations of all drill holes from southern Ontario.

REFERENCES

Fingas, J. 2013. Report on the Bannockburn 10% resampling program; unpublished report prepared by Fladgate Exploration Consulting Corporation for Crown William Mining Corporation, 25p.

McBride, D.E. 2013. Technical review of the Addington property, Kaladar Township, southern Ontario; unpublished report for Union Glory Gold Corporation, 107p.

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

Sangster, P.J., LeBaron, P.S., Charbonneau, S.J., Laidlaw, D.A., Wilson, A.C., Carter, T.R. and Fortner, L. 2012. Report of Activities 2011, Resident Geologist Program, Southern Ontario Regional Resident Geologist Report: Southeastern and Southwestern Ontario Districts and Petroleum Resources Centre; Ontario Geological Survey, Open File Report 6277, 72p.

HIGHLIGHTS

- **The use of talc, mica and other industrial mineral fillers in plastics has increased in recent years, led by the automotive industry as manufacturers attempt to produce lighter vehicles.**
- **There has been past production, and there are many known occurrences, of both carbonate-hosted and ultramafic intrusive-hosted talc in southeastern Ontario.**
- **High-grade, flake muscovite concentrations occur within metapelitic schists of the Flinton Group in well-defined, narrow belts through several townships of southeastern Ontario.**

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Talc and Mica: Industrial Mineral Fillers in Southeastern Ontario

The use of reinforced polymers based on talc, mica and other industrial mineral fillers has increased in recent years, led by the automotive industry as manufacturers attempt to produce lighter vehicles for improved fuel efficiency in gas-powered and hybrid automobiles and to improve the power-to-weight ratio in electric vehicles (Imerys 2016).

Roskill (2015) estimated that the world talc demand would increase by 2.3% annually from 2015 to 2020. Growth was projected to be led by the plastics industry, with demand also increasing in paint, food processing and technical ceramics markets. The largest market for talc has traditionally been in the paper sector. However, by 2019, plastics are expected to overtake paper as the largest talc-consuming application worldwide. In polypropylene, talc imparts the mechanical properties of strength and stiffness, among others, allowing plastic to replace heavier metal components in vehicles. The average talc content of a light European Union automobile more than doubled between 2006 and 2014 ("Talc: Global Industry, Markets and Outlook", report summary, www.roskill.com, accessed November 1, 2017).

The global production and consumption of mica has also increased significantly in the past few years and is expected to continue to grow at a rate of 2.6% annually from 2016 to 2024, reflecting high demand from several industries such as plastics, paints, construction, electronics and cosmetics. Mica can be delaminated into extremely thin sheets which are flexible, chemically inert, and very durable – properties that improve the qualities of some plastics. In the electronics industry, sheet mica is used as a thermal and electrical insulator. Fine-grained flake mica is added to paint to extend the shelf life and enhance the intensity and brightness of coloured pigments. The highly reflective aspect of flake mica also makes it useful in the production of cosmetics and toothpastes ("Mica Market... Global Industry Analysis, Size, Share, Growth, Trends, and Forecast 2016–2024", report summary, https://www.transparencymarketresearch.com/mica-market.html, accessed November 1, 2017).

Both talc and mica have been produced historically in southeastern Ontario since the late 1800s. The closure of the Canada Talc Mine in Madoc in 2010 leaves only 1 producing talc mine in Canada, the Imerys Talc Canada Inc. mine and micronizing plant near Timmins.

Past mica mining operations in Ontario produced sheet mica for electrical applications. There are currently no mica mining operations in Ontario and only one in Canada – a phlogopite mine in Quebec operated by Imerys. The phologpite is used to provide dimensional stability, increased stiffness and improved heat distortion temperature of plastic composites used in automotive applications ("Mica", www.imerys-perfmins.com, accessed November 1, 2017).

The geology of Ontario's talc and mica deposits and areas with potential for additional discoveries are described below.

Talc and Mica: Industrial Mineral Fillers in Southeastern Ontario

TALC

Talc deposits in the Grenville Province of southeastern Ontario can be separated into 2 types: those derived from alteration of carbonate rock and those derived from alteration of ultramafic rock. Many occurrences of both types within the Central Metasedimentary Belt are described in detail in LeBaron and van Haaften (1989).

Carbonate-Hosted Talc

Southeastern Ontario's largest talc mine, the Canada Talc Mine at Madoc, operated from 1896 to 2010 and produced about 1.5 million tonnes of talc from a high-purity deposit hosted by dolomitic marble. Talc is the first mineral to form during progressive metamorphism of siliceous dolomitic limestone, according to the reaction: 3 dolomite + 4 quartz + 1 H_2O = 1 talc + 3 calcite + 3 CO_2 (Winkler 1979).

With increasing temperature, tremolite is formed from the talc-calcite assemblage, followed by diopside-tremolite-quartz at higher grade metamorphism. These reactions indicate that talc should be present near the tremolite isograd in areas underlain by siliceous dolomitic marble, a model which can be applied to the Canada Talc deposit at Madoc and to the definition of new areas with potential for talc deposits.

The Canada Talc deposit occurs within marble of the Belmont Domain, an area of middle to upper greenschist facies metamorphism in which quartz and dolomite coexist in carbonate rocks, except in zones of higher metamorphic grade within thermal aureoles of intrusive bodies (Figure 1). The deposit occurs in a zone of tremolitic marble about 800 m northwest of the Moira Granite. The host rock dolomitic sequence includes thin quartzite beds and stromatolitic marble consisting of alternating quartz and dolomite laminae – evidence of a pre-metamorphism environment with the ingredients necessary for the formation of talc.

Previous explanations of the origin of the talc zone (Hewitt 1972) involve siliceous hydrothermal fluids originating from the Moira Granite intrusion being introduced into the dolomite sequence along structural channels. However, although structural control may have been involved in the circulation of fluids, it is not necessary to assume an external source of silica and water. The contribution of the Moira Granite to the formation of the talc deposit may have been only heat, in which case talc and tremolite alteration zones should be expected near the margin of the thermal aureole of any igneous intrusions, whether mafic or felsic, in areas of siliceous dolomitic marble of low regional metamorphic grade.

Based upon the deposit model described above, the Belmont Domain hosts geological conditions favourable for the formation of talc deposits. Figure 1 shows several talc occurrences within areas of marble intruded by mafic to felsic plutons such as the Moira Granite, Deloro Granite, Cordova Gabbro, Tudor Gabbro and Gawley Creek Syenite. This part of the Belmont Domain is characterized by middle to upper greenschist facies metamorphic assemblages, with higher grade assemblages noted adjacent to intrusive rocks (Easton 1992). Structural features, such as fold hinges and faults, within the favourable host rocks should also be investigated for talc mineralization. Topographic lows within areas of relatively resistant tremolitic marble may represent areas of shearing or faulting which may host softer, more talc-rich zones.

The high brightness and whiteness of carbonate-hosted ore at the Canada Talc Mine allowed operators of the mine to produce a range of products from high-purity talc to low-purity talc-dolomite filler and decorative aggregate without the need for flotation beneficiation.

Ultramafic Intrusive-Hosted Talc

A belt of talcose ultramafic rocks is intermittently exposed within a zone, up to 2 km wide, within the metavolcanic belt along the western margins of the Elzevir and Weslemkoon tonalitic batholiths, through Elzevir, Madoc, Grimsthorpe and Cashel townships (*see* Figure 1). These rocks are considered to be ultramafic intrusive phases of gabbroic rocks of the Canniff Complex, possibly a partially preserved ophiolite fragment (Easton and Ford 1994). They have been altered to various assemblages of talc, chlorite, serpentine, carbonate, hematite, magnetite and anthophyllite.

Talc and Mica: Industrial Mineral Fillers in Southeastern Ontario

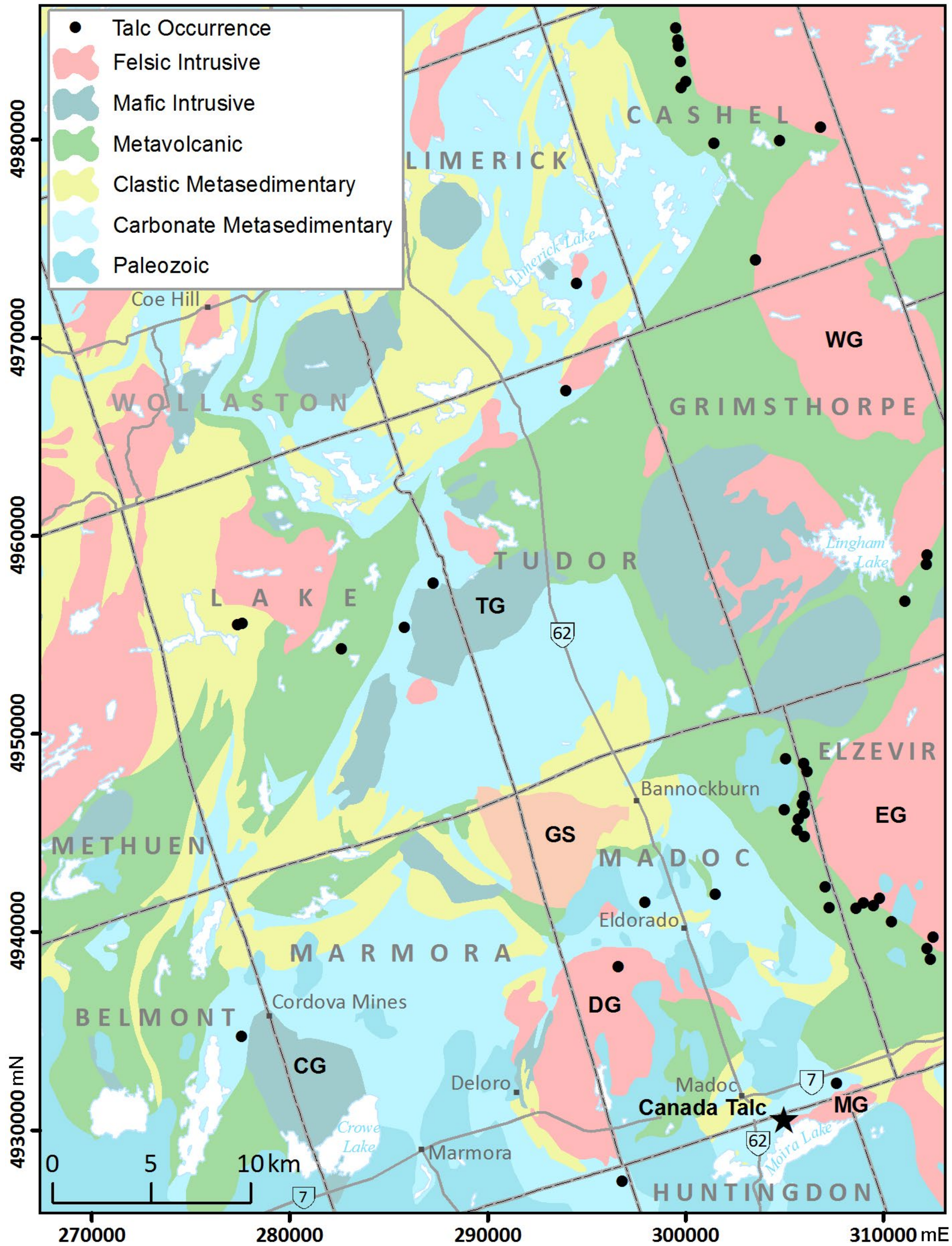

Figure 1. Geology and talc occurrences, Belmont Domain, southeastern Ontario; CG – Cordova Gabbro, DG – Deloro Granite, EG – Elzevir Granite, GS – Gawley Creek Syenite, MG – Moira Granite, TG – Tudor Gabbro, WG – Weslemkoon Granite. Talc locations *from* Mineral Deposits Inventory database (Ontario Geological Survey 2017); geology *from* Ontario Geological Survey (2011). Universal Transverse Mercator (UTM) co-ordinates are provided using the North American Datum 1983 (NAD83) in zone 17.

Talc and Mica: Industrial Mineral Fillers in Southeastern Ontario

Between 1883 and 1929, small quantities of talc-rich rock were quarried in Elzevir Township, near Actinolite, for use in roofing material, and in 1938, there was minor underground development on a talc occurrence in Cashel Township. Both occurrences, along with 14 others in the Elzevir–Cashel ultramafic belt, are described in LeBaron and van Haaften (1989), which describes the general characteristics of the talcose zones as follows:

> The talcose zones vary in width from 5 to 40 m, averaging 20 to 40% talc. Associated minerals include dolomite, serpentine, anthophyllite, chlorite, and magnetite. Less common are calcite, tremolite, and actinolite. Dimensions are difficult to determine because of poor exposure, but exposed widths of 15 m and lengths of 50 to 75 m are common. Both the McMurray occurrence (CL3) and the Cooper occurrence (MC6) are at least 40 m wide and over 300 m long.

The report also states that diamond drilling on the Cooper occurrence, Madoc Township, in 1985 indicated a 2 million tonne talc deposit to a depth of 30 m grading 30 to 33% recoverable talc.

Beneficiation tests done on composite samples from the Cooper occurrence and from 2 occurrences in Cashel Township are described in LeBaron and van Haaften (1989). Feed grades ranged from 30 to 47% talc, recoveries ranged from 75 to 90%, and dry brightness was close to values for high-quality commercial talc. It was determined that talc products from all 3 properties have potential for use in the paint, plastics and paper industries.

The Elzevir–Cashel belt of ultramafic rocks is well-situated for the production of talc with respect to access, infrastructure and proximity to markets in Ontario, Quebec and the northeastern United States.

Mica

All mica historically mined in southeastern Ontario has come from carbonatite-pyroxenite and pegmatite dikes that produced coarse sheet mica. This recommendation for exploration focuses on metasediment-hosted, flake muscovite deposits, as white mica is the preferred variety for most mineral filler applications and the grade and tonnage potential for stratabound, flake muscovite deposits is much greater than that of pegmatite-hosted deposits: in the order of millions of tonnes of 30 to 60% mica in the former and thousands of tonnes of less than 5% in the latter.

The most significant known flake muscovite deposit in southeastern Ontario is located in Kaladar Township (the Kaladar mica prospect, Figure 2). It consists of a muscovite schist up to 50 m thick, with a strike length of 2.5 km and containing up to 60% muscovite, with a possible resource of about 10 million tonnes to a shallow depth (non-National Instrument (NI) 43-101 compliant; Watts, Griffis and McOuat and Ontario Geological Survey 2002). Associated minerals include quartz, biotite, hematite and minor amounts of andalusite, sillimanite and tourmaline. It occurs within a belt of metapelitic gneisses and schists within the Clare River Synform, a narrow northeasterly trending structure within the Mazinaw Terrane of the Central Metasedimentary Belt (*see* Figure 2). The metapelitic rocks form part of the Flinton Group of metasedimentary rocks, which were deposited unconformably upon older rocks of the Grenville Supergroup between 1020 and 1155 Ma (Easton 2001).

The Kaladar mica prospect has been investigated by several companies since its discovery in 1978, including Omya Inc., Lacana Mining Corporation, and Koizumi Group Canada Ltd. In 1982, Koizumi extracted a 5000 tonne bulk sample from a test quarry in Lot 4, Concession 5, Kaladar Township (UTM co-ordinates: zone 18, 329490E 4940800N). The area of the test pit is currently designated by the Ministry of Natural Resources and Forestry as a Forest Conservation Reserve; however, strike extensions of the zone have potential for additional zones of muscovite concentration. In the area of the test pit and along strike to the southwest, creeks and beaver ponds follow the trend of the strata; therefore, it is possible that much of the muscovite schist is not exposed at bedrock, particularly in the nose of the Clare River Synform.

Metapelitic gneisses and schists of the Flinton Group also occur in a narrow belt trending northeastward through Kaladar Township and into Barrie Township, and in the Fernleigh Syncline through the central parts of Barrie and Clarendon townships (*see* Figure 2).

Talc and Mica: Industrial Mineral Fillers in Southeastern Ontario

Within the Kaladar–Barrie belt, Verschuren (1983) noted that there is a lower potential for high-grade muscovite of significant tonnage, but that a few high-grade zones (40 to 50% muscovite) occur. This area may warrant further investigation based on the observation that the muscovite zones may occupy topographic lows, as in the Clare River area.

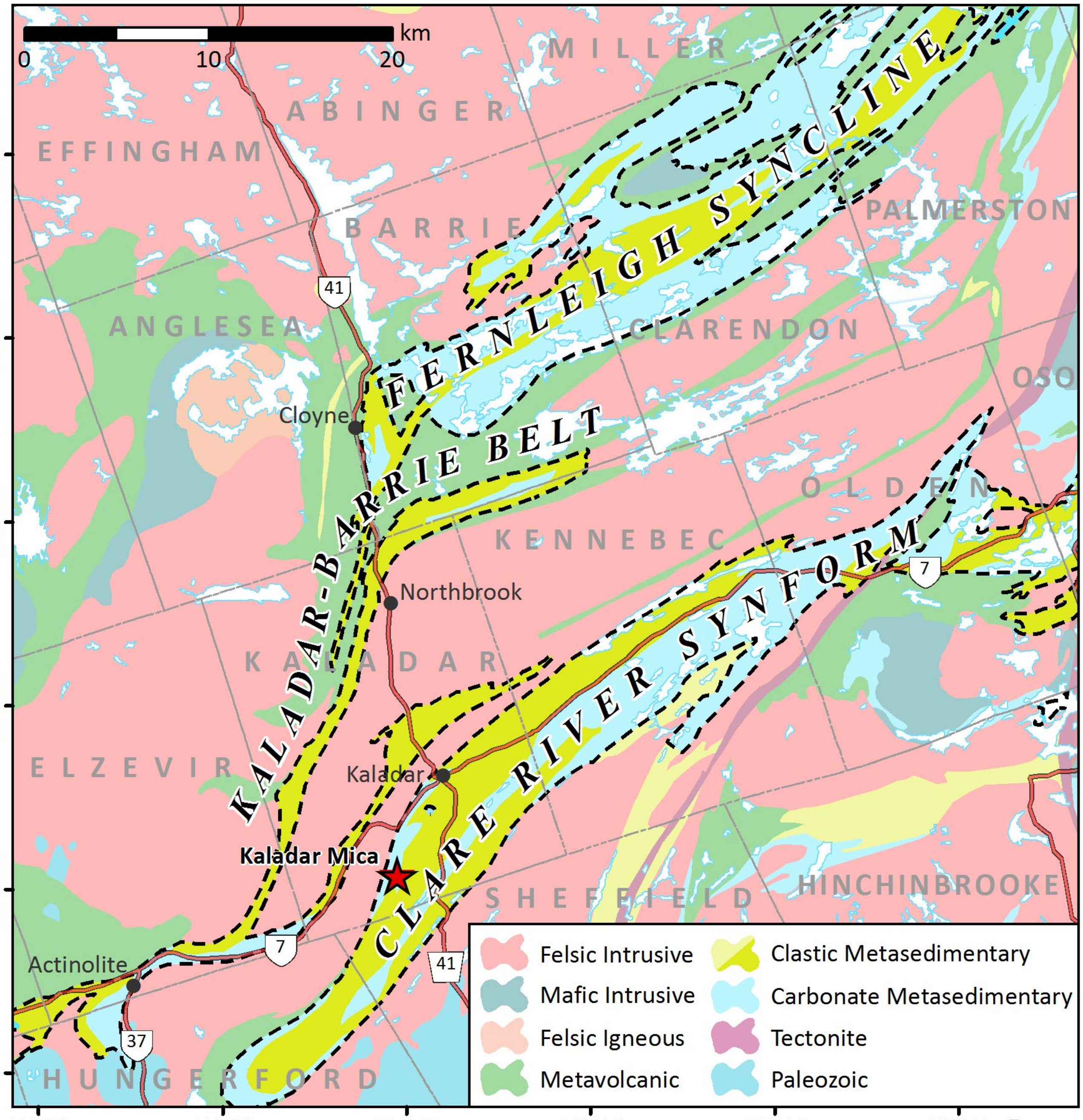

Figure 2. Location of predominantly Flinton Group metasedimentary rocks (lime green) hosting pelitic metasediments with potential for muscovite concentrations; geology *from* Ontario Geological Survey (2011). UTM co-ordinates are provided using NAD83 in zones 17 and 18.

Talc and Mica: Industrial Mineral Fillers in Southeastern Ontario

In the Fernleigh Syncline, muscovite occurs in a quartz-muscovite-staurolite schist that can be traced from Mississagagon Lake in Barrie Township to Ardoch near the eastern boundary of Clarendon Township. In this area, the flake size and abundance of muscovite increase and zones up to 20 m wide of potentially economic resources have been observed (Tibble and Ardoch properties; Watts, Griffis and McOuat and Ontario Geological Survey 2002).

CONCLUSION

An ideal mineral filler is inert, nonhazardous, has a low specific gravity, is nonabrasive, has consistent properties and can be produced at a relatively low cost. Talc and mica meet these requirements and many occurrences of each are known within the Central Metasedimentary Belt of southeastern Ontario. The industrial applications of both minerals, particularly in the plastics industry, is increasing.

Exploration for talc and mica are recommended within marble belts and ultramafic intrusive rocks of the Belmont Domain for the former, and in metapelitic rocks of the Flinton Group in the Mazinaw Terrane for the latter.

REFERENCES

Easton, R.M. 1992. The Grenville Province and the Proterozoic history of central and southern Ontario; *in* Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part 2, p.714-904.

——— 2001. Precambrian geology, Kaladar area; Ontario Geological Survey, Preliminary Map P.3441, scale 1:50 000.

Easton, R.M. and Ford, F.D. 1994. Geology of the Grimsthorpe area, Hastings and Lennox and Addington counties, Grenville Province; Ontario Geological Survey, Open File Report 5894, 153p.

Hewitt, D.F. 1972. Talc in Ontario; Ontario Geological Survey, Industrial Mineral Report 40, 52p.

Imerys 2016. Mineral solutions to create tomorrow's world; Imerys 2016 Annual Report [PDF document], www.imerys.com, accessed November 1, 2017, 60p.

LeBaron, P.S. and van Haaften, S. 1989. Talc in southeastern Ontario; Ontario Geological Survey, Open File Report 5714, 240p.

Ontario Geological Survey 2017. Mineral Deposit Inventory 2017, Ontario Geological Survey.

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

Roskill 2015. Talc: Global industry, markets and outlook; Roskill Market Report, available at www.roskill.com, 258p.

Verschuren, C.P. 1983. Flake muscovite potential of eastern Ontario; *in* Summary of Field Work, 1983; Ontario Geological Survey, Miscellaneous Paper 116, p.282-285.

Watts, Griffis and McOuat and Ontario Geological Survey 2002. Industrial mineral assessment and sampling of mica in central and eastern Ontario; Ontario Geological Survey, Open File Report 6086, 124p.

Winkler, H.G.F. 1979. Petrogenesis of metamorphic rocks, fifth edition; Springer–Verlag, New York, Heidelberg, Berlin, 348p.

HIGHLIGHTS

- **Desktop study of geophysical and digital elevation data reveals previously unrecognized structures and 6 interesting targets for gold mineralization in the Central Metasedimentary Belt of southern Ontario.**
- **Review of structural trends associated with gold deposits and occurrences are consistent with the trends of major structures suggested by geophysical and remote sensing data.**

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Recommendation for Gold Exploration in Southern Ontario Using GeologyOntario and OGSEarth

INTRODUCTION

A grassroots desktop study of southern Ontario's "gold camp" was undertaken, by the authors, using information readily available to the public through OGSEarth, an online application that draws on information stored in the Mines and Minerals Divisions' online data warehouse, GeologyOntario. Data provided by OGSEarth is available in Keyhole Markup Language (KML) format and can be viewed using such applications as Google Earth™ mapping service. OGSEarth can be accessed at https://www.mndm.gov.on.ca/en/minesz-and-minerals/applications/ogsearth).

Taking a predominantly structural approach, Mineral Deposit Inventory (MDI) records were reviewed for past gold producers, prospects and occurrences, and geology, magnetic (total field and 1st derivative), gravity and digital elevation maps were interpreted in an effort to outline new sectors for exploration.

Previously unrecognized structures and other geological features are interpreted below and areas of high potential for gold mineralization are recommended for further exploration.

GEOLOGY OF GOLD MINERALIZATION IN SOUTHERN ONTARIO'S GOLD CAMP

Figure 1 shows the geology and gold occurrences of the study area, an area loosely referred to as southern Ontario's "gold camp".

Regional Geology

The area of interest is centred on the Grimsthorpe Domain and includes the eastern part of the Belmont Domain (Elzevir Terrane) and the southwestern part of the Mazinaw Terrane, in the Central Metasedimentary Belt within the Grenville Province. The geology is dominated by mafic metavolcanic and clastic metasedimentary rocks of the Grimsthorpe Group (>1280 Ma), carbonate-dominated metasedimentary rocks of the Belmont Domain and clastic metasedimentary rocks of the Flinton Group (ca. 1155 Ma) (Easton 2008).

Gold Exploration in Southern Ontario Using GeologyOntario and OGSEarth

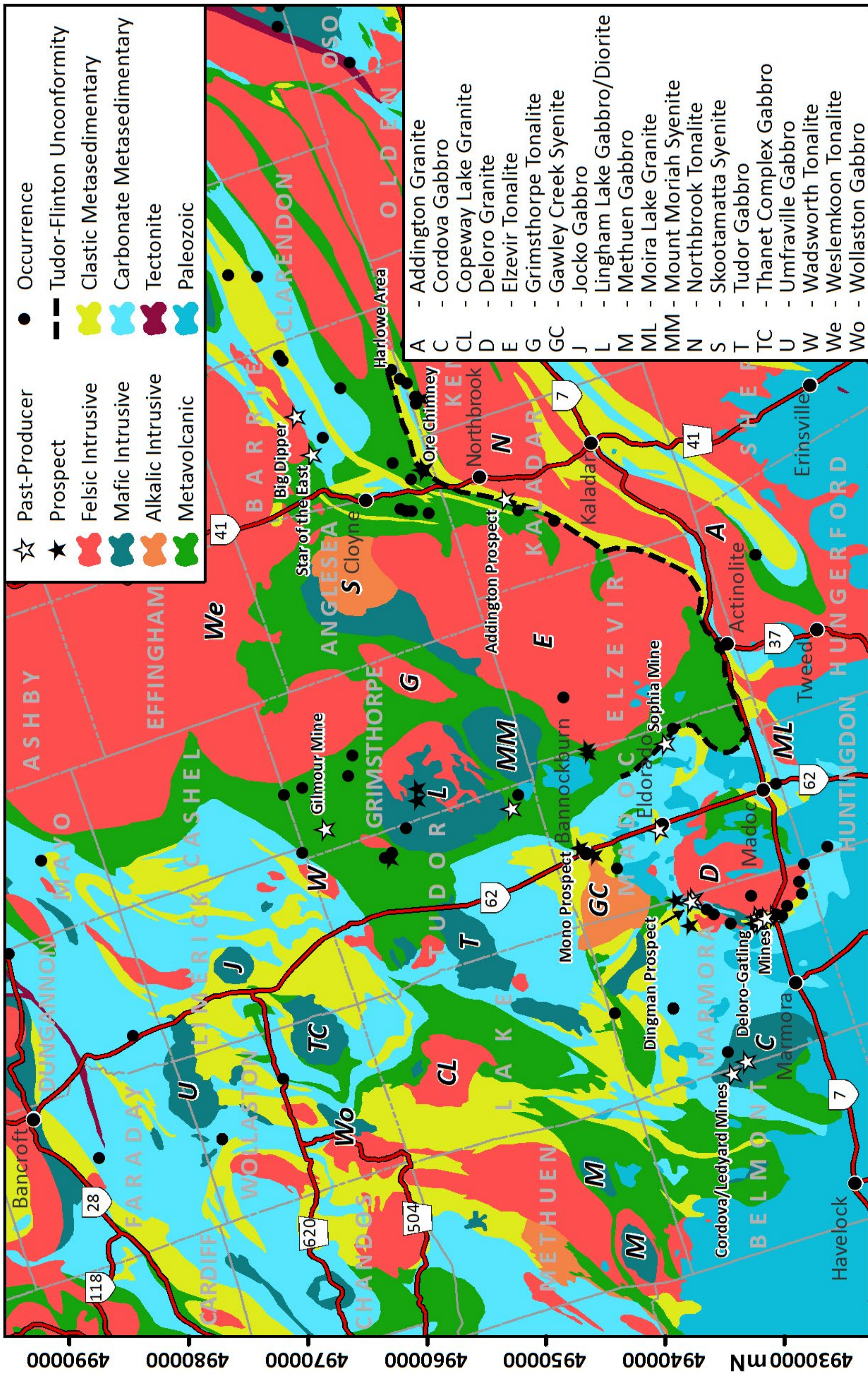

Figure 1. Regional geology of the study area with locations of past producers, prospects and gold occurrences shown. Figure created from MRD 126—Revision 1 (bedrock geology of Ontario, scale 1:250 000: OGS 2011) and MDI information (OGS 2017) available through OGSEarth. Universal Transverse Mercator (UTM) co-ordinates are provided using North American Datum 1983 (NAD83) in zones 17 and 18.

Gold Exploration in Southern Ontario Using GeologyOntario and OGSEarth

The base of the stratigraphic sequence in the area consists of tholeiitic mafic to intermediate metavolcanic and volcaniclastic rocks of the Canniff Complex and Tudor Formation. In the Madoc and Tudor townships area the Tudor Formation is overlain, unconformably, by the carbonate-dominated metasedimentary rocks of the Belmont Domain, while in the Elzevir and Kaladar Township area, the Tudor Formation is overlain, unconformably, by the quartz arenites, Temiskaming-style conglomerates and pelitic schists of the Flinton Group (ca. 1155 Ma) (Easton 1992). In the southern portion of the map area, Grenvillian rocks are overlain, unconformably, by subhorizontal Paleozoic limestones. Grenvillian supracrustal rocks are crosscut by several suites of intrusive rocks (Easton 1992, 2008).

Metamorphism in the area is generally of greenschist and lower-amphibolite facies and dated at 1130 to 1070 Ma (Easton 1992, 2000).

Controls for Gold Mineralization in Southern Ontario

In the past, the following controls for gold mineralization in southern Ontario have been suggested, as summarized in Sangster et al. (2014) (refer to Figure 1 for locations of deposits):

1. Intrusive margins: The Cordova and Deloro mines are quartz vein-type deposits that formed within intrusions, near the margins of the Cordova gabbro and the Deloro granite. The veins include pyrite, chalcopyrite, arsenopyrite, tourmaline and iron-bearing carbonates.

2. Metavolcanic-metasedimentary contact at the top of the Tudor Formation: The Sophia, Mono and Gilmour gold deposits occur in metavolcanic and metasedimentary rocks near the top of the Tudor Formation where it is in contact with the carbonate-dominated metasedimentary rocks of the Belmont Domain. Deposits consist of quartz and quartz-ankerite veins containing pyrite, pyrrhotite, arsenopyrite and traces of native gold. All are structurally controlled and occur within zones with pervasive iron carbonate and/or biotite-sericite alteration (Fingas 2013, 2015).

3. Flinton Group unconformity at the top of the Tudor Formation: The Addington and Ore Chimney mines and the Harlowe area occurrences represent concentrations of gold in metavolcanic and metasedimentary rocks at the top of the Tudor Formation, immediately beneath the unconformity with the Flinton Group sedimentary rocks (which include Temiskaming-type conglomerates), along the northern margin of the Northbrook granodioritic pluton (Moore and Morton 1986). Gold mineralization consists of quartz veins with tourmaline, pyrite, chalcopyrite, galena, sphalerite and tetrahedrite.

It should be noted that the Dingman deposit stands alone as a structurally controlled stockwork deposit with disseminated gold, confined to a small intrusive body. The Dingman deposit (11.6 MT @ 0.97 g/t Au) has potential for a low-grade, high-tonnage operation (Sangster et al. 2014, p.50-51).

METHODOLOGY

For this compilation, geology, geophysics and digital topographic elevation maps were downloaded “as is” from OGSEarth without any data manipulation. The geophysical maps were interpreted for linear and circular features and geology maps were used as lithological controls.

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Mineral Deposit Inventory (MDI) records were downloaded for past producers, prospects and occurrences where gold is the primary commodity. Discretionary occurrences were not included. Occurrences are as defined by MNDM (2012) and Wilson et al. (2008). For additional details on certain occurrences, references listed in the MDI records were consulted.

MDI records for past producers and prospects were reviewed and the general orientations of veins were recorded. Although much of the data is based on historical documents and must be refined, a number of broad orientation clusters of veins are observed in all parts of the study area (Figure 2).

INTERPRETATION

Figures 3 to 6 show the maps of the study area, with interpretation.

Gravity Map

Figure 3 shows the gravity map of the study area with the outline of positive gravity anomalies. With the exception of the Deloro Pluton and its associated gold occurrences, there is a clear association of a positive gravity anomaly with the southern Ontario gold camp. The positive gravity anomaly appears to be associated with the Caniff and Tudor mafic volcanic rocks, with a negative gravity anomaly at its core, associated with the Elzevir Batholith (*see also* Real and Thomas 1987).

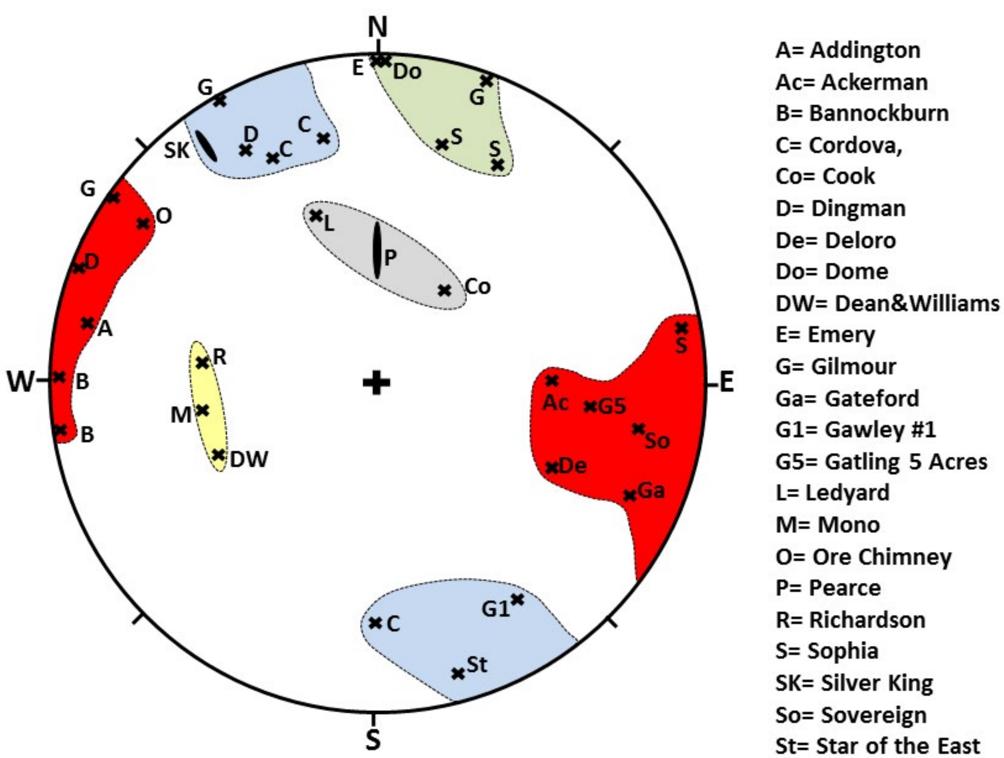

Figure 2. Stereographic representation (Wulff) of gold-quartz veins, represented by poles, from the past producers and prospects of southern Ontario. Broad groupings occur at NS-030°, shown in red; 065°, in blue; 100°/80°S, in green; 350°/45°E, in yellow and 090°/30°S, in grey. Data *from* LeBaron (1991), Carter (1984) and Malzac, Carter and Springer (1985).

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Other positive gravity anomalies occur above the Cordova Pluton area just west of the town of Marmora, associated with the Umfraville mafic intrusive complex, south of the town of Bancroft, and in the northeast portion of the study area. A weak positive gravity anomaly (not outlined) extends northeastward from gold occurrences near the towns of Cloyne and Northbrook to the positive gravity anomaly in the northeast portion of the study area.

Magnetic and Digital Elevation Maps

Vertical gradient magnetic (Figure 4), 1st derivative magnetic (Figure 5) and digital elevation maps (Figure 6) are excellent tools to outline circular features, linear structures and large-scale fabrics.

CIRCULAR FEATURES / INTRUSIONS

The vertical gradient magnetic map is particularly useful for picking out intrusive rocks, generally identified by their circular features. Intrusive rock signatures are grouped into (*see* Figure 4) the following:

Magnetic High: Includes Skootamatta, Mt. Moriah, Gawley Creek, Tudor, Umfraville, Wollaston Lake, Methuen intrusions and another intrusion in the central part of Chandos Township.

Magnetic Low: Includes Cordova, Lingham Lake (although the northernmost part of Lingham Lake shows a semi-circular magnetic high), Weslemkoon, Wadsworth, Northbrook, Addington, Grimsthorpe and Elzevir intrusions.

Complex: Includes Thanet, Deloro, Moira Lake, Jocko Lake and the Copeway Lake intrusions as well as another intrusion that is straddling the southern portion of the Madoc–Elzevir township boundary but not observed at surface on the map by Diprisco et al. (2001).

LINEAR FEATURES AND STRUCTURAL FABRICS

Total field magnetic, 1st derivative magnetic and digital elevation maps are also very effective for picking out structural fabrics and lineaments. Figures 5 and 6 show interpretations of structural fabrics and lineaments on the 1st derivative magnetic and digital elevation maps. The following observations are made:

Two dominant orientations of structures are evident: one trending 060°-070° and the other, north-trending. The age relationship between the 2 families of structures is unclear from this desktop interpretation but the structures appear to be mutually crosscutting, therefore possibly synchronous.

These dominant structures are shown on Figure 7, grouped as “corridors”, with the Marmora–Northbrook, Coe Hill and Huntingdon Township structures oriented at 060°-070° and the Haverlock–Gilmour and Actinolite-Cloyne, oriented northward.

Perhaps not surprisingly, these orientations correspond with the dominant orientations of mineralized gold-quartz veins from past producers and prospects of the area (*see* Figure 2).

OTHER STRUCTURES

Several structures are interpreted trending at 120° to 300°, one of which is observed immediately north of the Sophia past producer, where many mineralized veins coincide with that orientation. Another structure of same orientation is interpreted within the Elzevir Batholith.

Only one structure is observed with an east trend, cutting the Thanet and Wollaston Lake gabbroic intrusions in Limerick Township.

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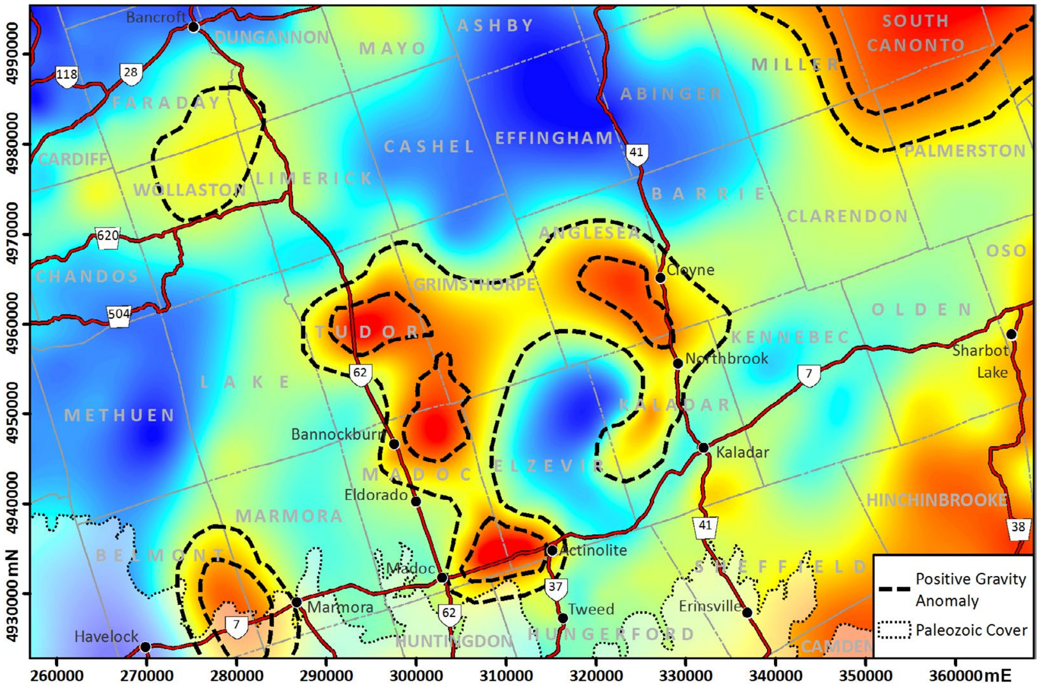

Figure 3. Gravity map of the study area with overlain general outlines of positive gravity anomalies as interpreted from OGSEarth. Background is from GDS1035 (OGS 2003a).

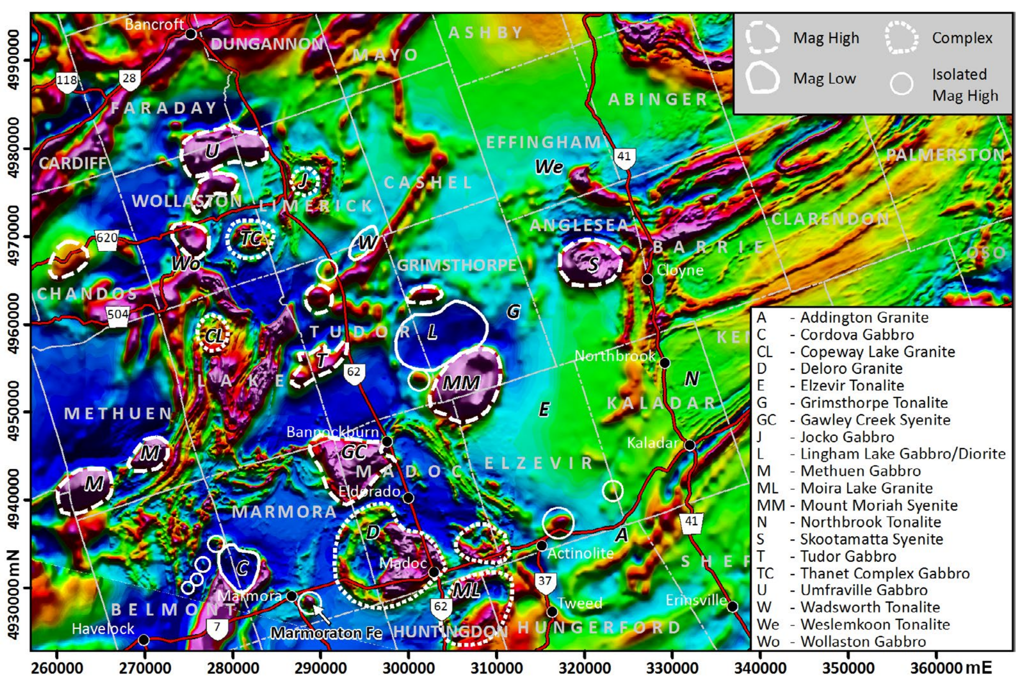

Figure 4. Total magnetic map with interpreted intrusions overlain in white (interpreted from OGSEarth). Intrusion outlines are based on magnetic high and low circular features. Background is a snapshot of data obtained from a composite of GDS1035 (OGS 2003a), GDS1018—Revised (OGS 2003b) and GDS1234 (OGS 2010).

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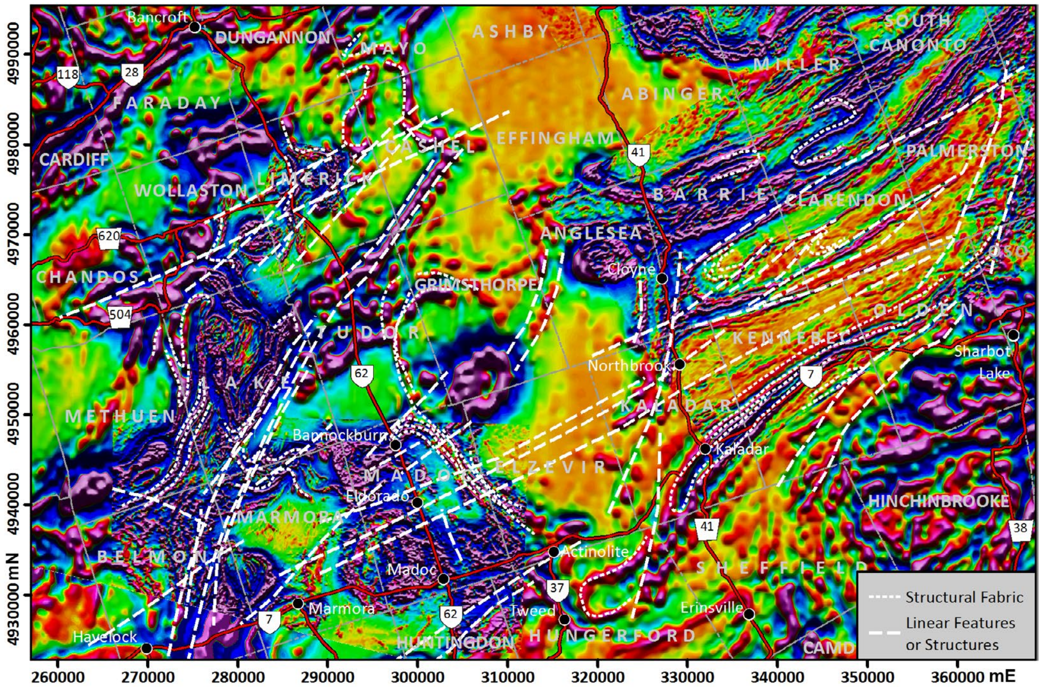

Figure 5. First derivative magnetic map with interpreted structures and structural fabrics overlain in white as interpreted from OGSEarth. Background image is from a composite of GDS1035 (OGS 2003a), GDS1018—Revised (OGS 2003b) and GDS1234 (OGS 2010).

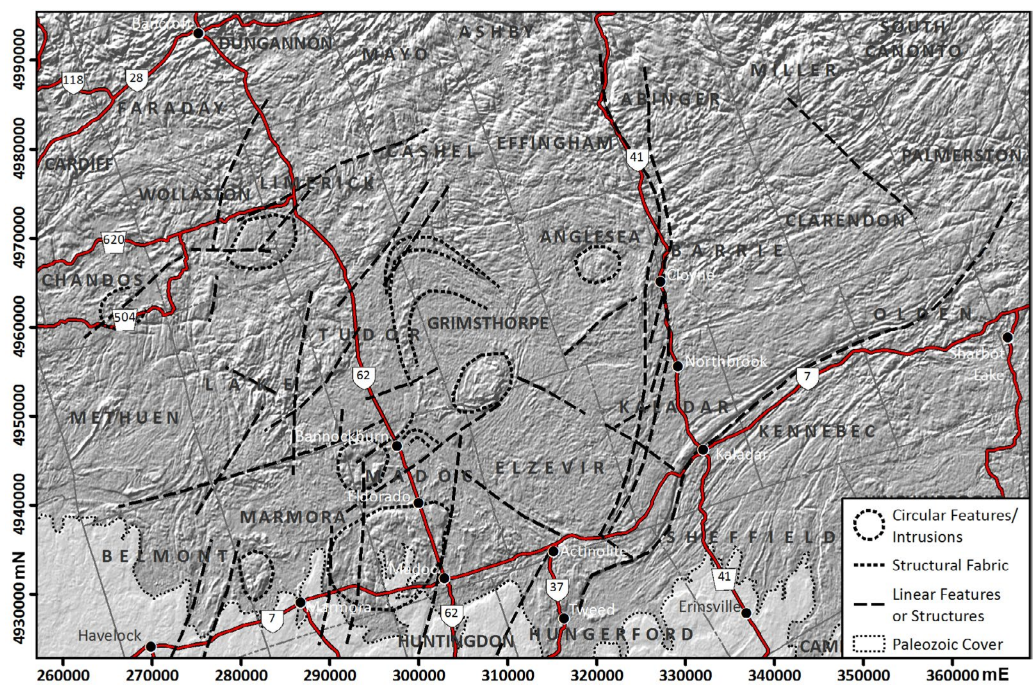

Figure 6. Digital elevation map with interpreted geological features overlain in black as interpreted from OGSEarth. Background *from* MRD142 (Shirota and Barnett 2004).

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CONCLUSIONS

Historically, guides for gold exploration in southern Ontario included

1. lithological contacts, including contacts with intrusions that provide a competency contrast with surrounding rocks (especially where they are crosscut by structures);
2. proximity to the upper contact of the Tudor mafic volcanic cycle where they are overlain unconformably by the Flinton Group clastic sedimentary rocks (including Temiskaming-type conglomerates) or the carbonate-dominated metasedimentary rocks of the Belmont Domain;
3. low metamorphic grade (greenschist to lower amphibolite) rocks; and
4. small, deformed intrusions such as the granitoid that is host to the Dingman prospect.

This study suggests the following additional controls to guide gold exploration in southern Ontario:

1. association with positive gravity anomalies,
2. association with north-trending structures (350°-035°),
3. association with northeast-trending structures (060°-070°), and
4. isolated magnetic anomalies such as the one associated with the Cordova Mine.

RECOMMENDATIONED TARGETS

By overlapping interpretations of all 4 maps (Figure 7), the following observations are made and targets emerge. Six preliminary target areas are recommended for exploration, in order of decreasing priority:

1. The area located at the upper contact of the Tudor Formation mafic volcanic rocks along the Havelock–Gilmour corridor. The area is also located at the north edge of, and within the positive gravity anomaly associated with, the gold camp. In the same area, 3 small intrusions (the Wadsworth Tonalite and 2 unnamed circular intrusions southwest of the Wadsworth) may provide potential for Dingman-style gold mineralization as well as rheological contrasts favourable to provide sinks for gold mineralization.
2. The Cloyne–Northbrook area where the Marmora–Northbrook corridor intersects the Actinolite–Cloyne corridor within the positive gravity anomaly of the gold camp. Targets include the Marmora–Northbrook and Actinolite–Cloyne breaks, the upper contact of the Tudor Formation and the eastern contact of the Elzevir Batholith.
3. The Haverlock–Gilmour corridor in the area west of the Cordova Pluton where it is located in the western part of a positive gravity anomaly. A number of prospective isolated magnetic highs are also observed within the corridor.
4. The Elzevir Batholith, where it is intersected by the Marmora–Northbrook corridor. These intrusions have not typically been targeted in southern Ontario and the interpretation of these favourable structures cutting through them may present opportunities. The Silver King occurrence is an example within the Elzevir Batholith (northeast-trending veins).
5. The Coe Hill corridor, where previously unrecognized structures, trending 065° and 090°, are interpreted, cutting through the Thanet, Jocko and Wollaston gabbroic intrusive complexes. In the same area, 3 structures parallel to the northern portion of the Haverlock–Gilmour corridor are also interpreted. The area flanks the Umfraville positive gravity anomaly.
6. The Huntingdon Township corridor where it is interpreted to cut the Moira Lake Granite. The target is, however, located underneath Paleozoic sedimentary cover.

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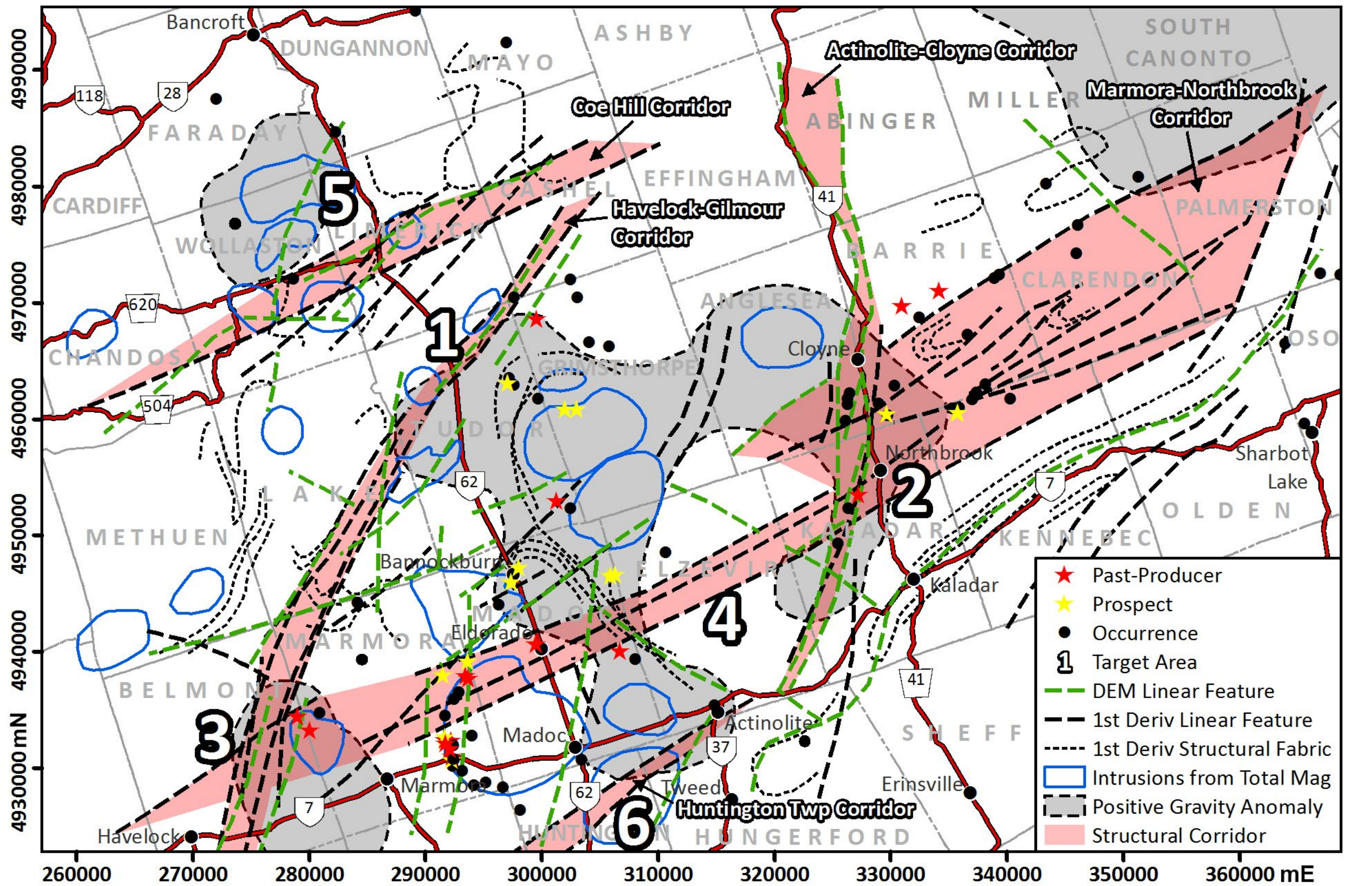

Figure 7. Compilation and target map showing overlain interpretations of structures from magnetic and digital elevation maps, positive gravity anomaly contours and gold occurrences.

REFERENCES

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

Di Prisco, G., Hammar, J. and Easton, R.M. 2001. Precambrian geology Elzevir area, south half; Ontario Geological Survey, Preliminary Map P.3181, scale 1:20 000.

Easton, R.M. 1992. The Grenville Province and the Proterozoic history of central and southern Ontario; *in* Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part 2, p.714-904.

——— 2000. Metamorphism of the Canadian Shield, Ontario, Canada. II. Proterozoic Metamorphic History; Canadian Mineralogist, v.38, p.319-344.

——— 2008. Precambrian geology of western Grimsthorpe Domain, Grenville Province; Ontario Geological Survey, Preliminary Map P.3600, scale 1:50 000.

——— 2017. The Grenville Orogen in Ontario, its geology and metallogeny: What's old is new again; *in* A second opinion on the high-grade metamorphic potential of the Grenville, Prospectors and Developers Association of Canada, International Convention 2017, Technical Program presentation, March 5, 2017.

Gold Exploration in Southern Ontario Using GeologyOntario and OGSEarth

Fingas, J. 2013. Report on the Bannockburn 10% resampling program; unpublished report by Fladgate Exploration Consulting Consulting Corporation for Crown William Mining Corporation, 20p.

——— 2015. Report on the 2015 trench mapping program, Bannockburn gold project, Madoc Township, Ontario, Canada, southern Ontario mining division, NTS 31C/12; unpublished report by Fladgate Exploration Consulting Consulting Corporation for Crown William Mining Corporation, 25p.

LeBaron, P.S. 1991. Exploration for gold in southeastern Ontario, 1980–1990; Ontario Geological Survey, Open File Report 5808, 147p.

Lumbers, S.B. 1969. Geology of Limerick and Tudor townships, Hastings County; Ontario Department of Mines, Geological Report 67, 110p.

Matzac, J., Carter, T.R. and Springer, J.S. 1985. Base metal, molybdenum and precious metal deposits of the Madoc–Sharbot Lake area, southeastern Ontario; Ontario Geological Survey, Open File Report 5548, 374p.

Moore, J.M., Jr. and Morton, R.L. 1986. Geology of the Marble Lake area, counties of Frontenac and Lennox and Addington; Ontario Geological Survey Report 238, 63p.

Ministry of Northern Development and Mines 2012. Mineral Deposit Inventory: Data entry manual; internal document, Ministry of Northern Development and Mines, 261p.

Ontario Geological Survey 2017. Mineral Deposit Inventory; Ontario Geological Survey, Mineral Deposit Inventory, online database.

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

——— 2010. Ontario airborne geophysical surveys, magnetic and electromagnetic data, grid and profile data (ASCII and Geosoft® formats) and vector data, Bancroft area—Purchased data; Ontario Geological Survey, Geophysical Data Set 1234.

——— 2003a. Single master gravity and aeromagnetic data for Ontario, ASCII, Excel® and Access® formats; Ontario Geological Survey, Geophysical Data Set 1035.

——— 2003b. Ontario airborne geophysical surveys, magnetic data, grid and profile data, ASCII and Geosoft® formats, Kaladar–Marmora area; Ontario Geological Survey, Geophysical Data Set 1018—Revised.

Real, D. and Thomas, M.D. 1987. Gravity models within the southern Central Metasedimentary Belt, Grenville Province, Ontario; *in* Current Research, Part A, Geological Survey of Canada, Paper 87-1A, p.763-772.

Sangster, P.J., LeBaron, P.S., Charbonneau, S.J., Laidlaw, D.A., Debicki, R.L., Wilson, A.C., Halet, S.E., Carter, T.R. and Fortner, L. 2014. Report of Activities 2013, Resident Geologist Program, Southern Ontario Regional Resident Geologist Report: Southeastern Ontario and Southwestern Ontario Districts and Petroleum Resources Operations; Ontario Geological Survey, Open File Report 6296, 83p.

Shirota, J. and Barnett, P.J. 2004. Lineament extraction from Digital Elevation Model (DEM) for the Province of Ontario; Ontario Geological Survey, Miscellaneous Release—Data 142.

Tessier, A.C., LeBaron, P.S., Charbonneau, S.J., Laidlaw, D.A., Wilson, A.C. and Fortner, L. 2017. Report of Activities 2016, Resident Geologist Program, Southern Ontario Regional Resident Geologist Report: Southeastern Ontario and Southwestern Ontario Districts and Petroleum Operations; Ontario Geological Survey, Open File Report 6329, 73p.

Wilson, A.C., Rowell, D.J., Seim, G.Wm. and Debicki, R.L. 2008. Procedural guidelines for provincially significant mineral potential mineral resource assessments; Ontario Geological Survey, Open File Report 6141, 91p.

HIGHLIGHTS

- **Magmatic nickel-copper-cobalt deposits associated with the Sudbury Igneous Complex.**
- **Base metal occurrences associated with mafic intrusions.**
- **Cobalt–Gowganda vein deposits.**
- **Huronian copper-gold occurrences are characterized by anomalous cobalt contents.**

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Cobalt Mineralization in the Sudbury District

The US Geological Survey's Mineral Commodity Summaries 2017 for cobalt confirms that most of the cobalt produced in 2016 was a by-product from nickel mining (US Geological Survey 2017). They also predict that the global cobalt market is shifting from surplus to deficit because of increased demand of rechargeable batteries and growth in the aerospace industry. In 2016, superalloys accounted for 45% of the cobalt consumption in the United States. Cobalt exploration is fueled by the prediction that cobalt consumption will increase at a faster pace than supply.

In the Sudbury District, cobalt is found in 4 mineralization types: magmatic nickel-copper-cobalt mineralization related to the Sudbury Igneous Complex (SIC) of the Sudbury Basin; base metal occurrences (nickel-copper and copper) associated with mafic intrusions; silver-cobalt vein mineralization in the Cobalt Embayment; copper-gold (cobalt) mineralization in the Huronian Supergroup south of the Sudbury Basin (possible iron oxide-copper-gold deposits). Figure 1 shows the cobalt potential in the Sudbury District based on cobalt mineralization data in the Ontario Mineral Deposit Inventory (MDI) (Ontario Geological Survey 2017). The hatched area represents a general area of interest for arsenide-silver-cobalt veins spatially related to Nipissing intrusions in the Huronian Supergroup.

The nickel mines of the Sudbury Basin produced 1882 tonnes of cobalt in 2016 (Glencore 2017; Vale 2017). With 8 producing nickel mines in the district, and 2 well-advanced nickel projects, Sudbury will continue to be a source for world cobalt production. Although most of the Sudbury Basin mining lands are occupied by active claims, mining leases and patented claims, the stakeholders continue aggressive exploration and development.

Outside the basin, the MDI database records 16 mafic intrusion-hosted base metal occurrences that contain cobalt. These are generally associated with the East Bull Lake Intrusive Suite (the Agnew, East Bull Lake and River Valley Complexes) or Nipissing gabbroic intrusions. Exploration for these types of deposits has focused on nickel, copper or platinum group metals. Cobalt is deemed an accessory, value-added commodity.

Cobalt has not, in the past, been a primary target for exploration in the Sudbury District. However, the district does include areas with cobalt potential: the southwestern portion of the Cobalt Embayment, host to the Cobalt–Gowganda mining camps; and the Huronian Supergroup south of the Sudbury Basin, host to a number of small-scale gold mines with anomalous cobalt contents, possibly modified iron-oxide copper gold deposits (*see* Figure 1).

The silver-cobalt veins that are characteristic of the Cobalt–Gowganda mining camps are described in the literature as "arsenide silver-cobalt veins" (Ag-Co-Ni-Fe) (Ruzicka and Thorpe 1996; Andrews et al. 1986)

Cobalt Mineralization in the Sudbury District

and "five element veins" (Ni-Co-As-Ag-Bi) (Kissin 1992; Marshall 2008). The veins commonly occur at or near the contact between Nipissing diabase intrusions and Cobalt Group sedimentary rocks, particularly the Gowganda Formation (Petruk 1971; Ruzicka and Thorpe 1996). The Cobalt–Gowganda silver-cobalt camps produced 11 200 tonnes of cobalt between 1904 and 1989 (Guindon et al. 2016). Andrews et al. (1986) defined a zone of economic importance in the area north and east of the Cobalt Embayment, including the Cobalt and Gowganda areas. However, the primary target units for cobalt, the Nipissing intrusions and the Gowganda Formation of the Cobalt Group occur throughout the embayment, in both the Sudbury and Kirkland Lake districts (Suma-Momoh 2017). The southwestern quadrant of the embayment in the Sudbury District has a number of indicators suggesting the potential for silver-cobalt vein-type mineralization in the area. The Ontario MDI lists 7 vein-type mineral occurrences in the area with cobalt as a primary or secondary commodity. Lake sediment geochemical

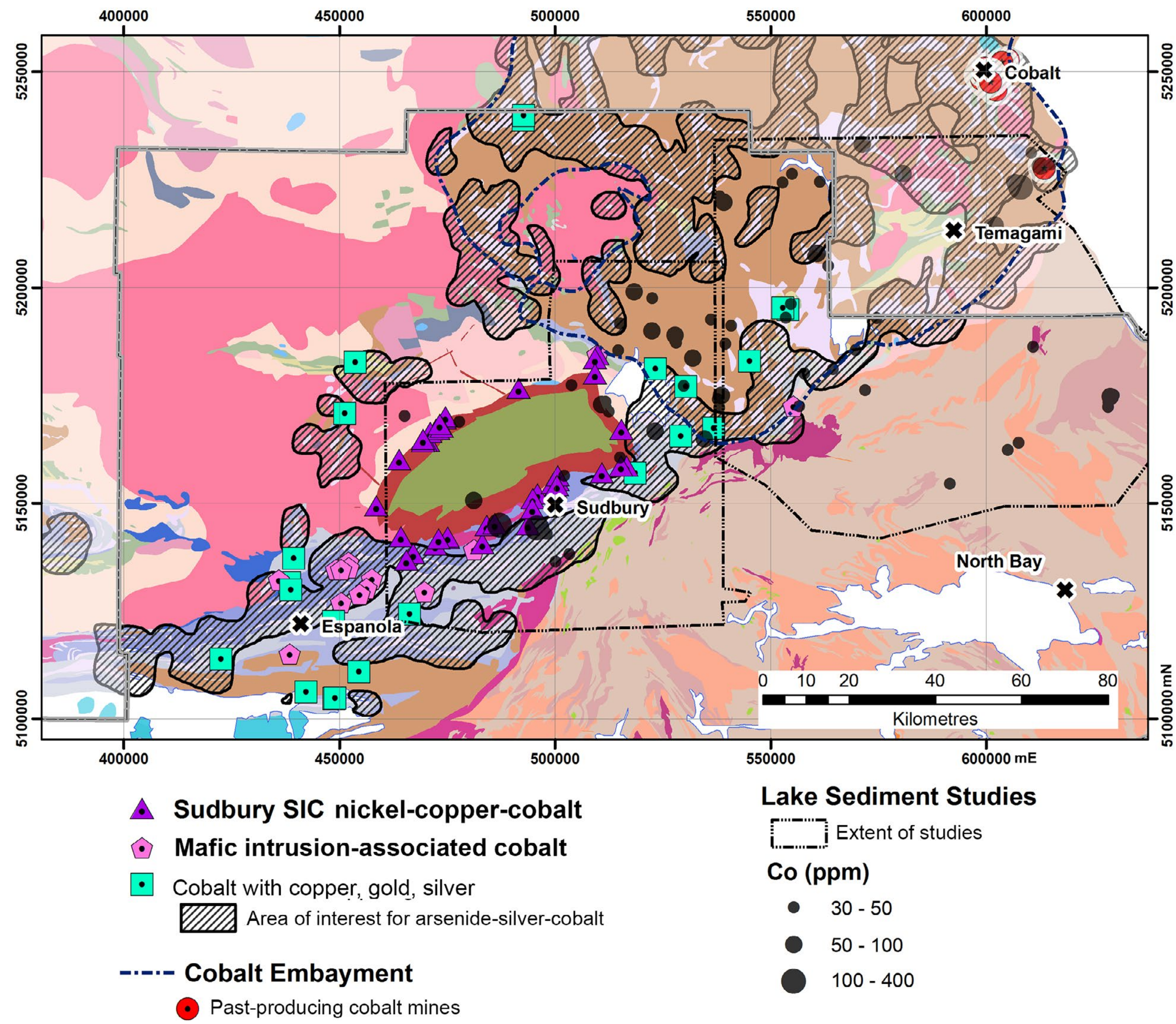

Figure 1. Cobalt potential in the Sudbury District. Cobalt occurs with Sudbury SIC nickel-copper-cobalt deposits, mafic intrusion base-metal occurrences, and in the Huronian Supergroup with arsenide-silver-cobalt veins and copper-gold occurrences. (Bedrock geology *from* Ontario Geological Survey 2011; Universal Transverse Mercator (UTM) co-ordinates are provided using North American Datum 1983 (NAD83) in zone 17.)

Cobalt Mineralization in the Sudbury District

studies carried out over part of the Temagami and Sudbury areas (Takats and Dyer 2004; Dyer, Takats and Felix 2004, respectively) show anomalous cobalt values (*see* Figure 1), some of which correspond to known cobalt occurrences. Those with no known corresponding occurrences may indicate that the source is as yet undiscovered, or is elsewhere in the catchment basin of the lake. The area of interest for the arsenide silver-cobalt veins shown in Figure 1 is a generalized representation, based on the association of known occurrences with the Nipissing intrusions, within the intrusions themselves, or in the adjacent bedrock within up to 150 to 200 m of the intrusive contact (Petruk 1971; Andrews et al. 1986). It should be noted that while most of the MDI points fall within the area of interest, not all do. Many lake sediment anomalies also fall outside the area. Possible explanations for these discrepancies can only be determined through ground-truthing.

Anomalous cobalt contents may be associated with copper-gold occurrences in the Huronian Supergroup south of the Sudbury Basin, as reported by Gates (1991) and confirmed by Schandl, Gorton and Davis (1994). The Ontario MDI lists 14 occurrences in the area, with cobalt as a primary or secondary commodity, that are neither magmatic nor mafic intrusion-related (*see* Figure 1). Cobalt anomalies in the lake sediments (Dyer et al. 2004) are fewer in this area than in the Cobalt Embayment (*see* Figure 1), but the presence of Nipissing intrusions in the sedimentary rocks suggests that there could be cobalt potential. Historically, this area was not targeted for cobalt exploration, and occurrences were not necessarily analysed for cobalt. With the expected surge in demand for cobalt and with the iron oxide-copper-gold model in mind, these copper-gold occurrences should be re-examined for cobalt potential.

In the Sudbury District, cobalt has generally been considered as ancillary to nickel-copper, be it in the SIC deposits, or in the mafic intrusions. However, there are strong indications that cobalt-bearing deposits may occur in the Huronian, either as silver-cobalt veins in the Cobalt Embayment or associated with copper-gold deposits south of the Sudbury Basin. Thus prospecting and exploration for cobalt in these areas is recommended.

REFERENCES

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

Dyer, R.D., Takats, P.A. and Felix, V.E. 2004. Sudbury area lake sediment geochemical survey; Ontario Geological Survey, Open File Report 2126, 106p.

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

Glencore 2017. Production report for the 12 months ended 31 December 2016; Glencore News Report, released February 2, 2017, PDF document, available at http://www.glencore.com/media/news/ , 19p.

Guindon, D.L., Farrow, D.G., Hall, L.A.F., Daniels, C.M., Debicki, R.L., Wilson, A.C., Bardeggia, L.A. and Sabiri, N. 2016. Report of Activities 2015, Resident Geologist Program, Kirkland Lake Regional Resident Geologist Report: Kirkland Lake and Sudbury Districts; Ontario Geological Survey, Open File Report 6318, 106p.

Kissin, S.A. 1992. Five-element (Ni-Co-As-Ag-Bi) veins; Geoscience Canada, v.19, p.113-124.

Marshall, D. 2008. Economic geology models 2. Melt inclusions of native silver and native bismuth: A re-examination of possible mechanisms for metal enrichment in five-element deposits; Geoscience Canada, v.35, p.137-145.

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

——— 2017. Mineral Deposit Inventory; Ontario Geological Survey, Mineral Deposit Inventory, online database.

Petruk, W. 1971. General characteristics of the deposits; The Canadian Mineralogist, v.11, p.76-107.

Cobalt Mineralization in the Sudbury District

Ruzicka V. and Thorpe, R.I. 1996. Arsenide vein-silver, uranium; in Geology of Canadian Mineral Deposit Types; Geological Survey of Canada, Geology of Canada, no.8, p.287-306. (Also available in Geological Society of America, The Geology of North America, v.P-1.)

Schandl, E.S., Gorton, M.P. and Davis, D.W. 1994. Albitization at 1700 +/- 2 Ma *in* the Sudbury–Wanapitei Lake area, Ontario: Implications for deep-seated magmatism *in* the Southern Province; Canadian Journal of Earth Science. v.31, p.597-607.

Suma-Momoh, J. 2017. Cobalt potential in the Kirkland Lake District; *in* Ontario Geological Survey, Resident Geologist Program, Recommendations for Exploration 2016–2017, p.54-57.

Takats, P.A. and Dyer. R.D. 2004. Temagami area lake sediment geochemical survey, northeastern Ontario; Ontario Geological Survey, Open File Report 6144, 113p.

US Geological Survey 2017, Mineral commodity summaries 2017; U.S. Geological Survey, PDF document, 202p., https://doi.org/10.3133/70180197 (Cobalt, p.52-54).

Vale 2017. Form 20-F. Annual report pursuant to Section 13 or 15(d) of the Securities Exchange Act of 1934. For the fiscal year ended: December 31, 2016; Vale annual report, released April 10, 2017, PDF document, available at http://www.vale.com/canada/EN/investors/information-market/annual-reports/20f/Pages/default.aspx , 289p.

Gold in the Huronian Supergroup, Sudbury District

HIGHLIGHTS

- **Soda-metasomatized copper-gold occurrences of the Huronian Supergroup – possible iron-oxide-copper-gold–related deposits.**
- **Paleoplacer gold in the Mississagi and Lorrain formations – possible Witwatersrand-type deposits.**

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Gold occurrences in the Huronian Supergroup of the Sudbury District have been recognized since the late 1800s (Gordon et al. 1979; Gates 1991). The 2 principal gold mineralization styles are soda-metasomatized (Gates 1991), possibly iron oxide-copper-gold (IOGC)–related (Schandl and Gorton 2007), and paleoplacer gold (Innes and Colvine 1979). Areas of potential interest for these 2 mineralization styles in the Sudbury District are shown in Figures 1 and 2, respectively.

The potential for IOCG-related deposits has been discussed by Farrow (2016), and the characteristics shared between the defined IOCG deposit model (e.g., Williams et al. 2005) and the soda-metasomatized occurrences in the Huronian Supergroup within the Sudbury District have been extensively studied and presented by Schandl and Gorton (2007).

The shared characteristics observed by Schandl and Gorton (2007), for the example of the Scadding gold mine, are

- regional soda-metasomatism (albite alteration);
- anomalously elevated rare earth elements (REE)-cobalt-copper-gold contents;
- titanium-poor (magnetite and hematite) iron oxides—which are typical of IOCG deposits, but at the Scadding Mine, oxides are subordinate to sulphides;
- hydrothermal brecciation;
- structurally controlled; and
- localized chloritization.

The area exhibiting these characteristics is widespread in the Sudbury District (Gates 1991), as seen in Figure 1. There is a concentration of gold occurrences within the soda-metasomatized zone. Some of these occurrences were mined on a small scale, and active exploration of this mineralization type is on-going. The presence of extensive alteration halos provides an ideal vector toward these deposits, as will the recognition of the more proximal criteria listed above.

The potential for paleoplacer gold occurrences within the Huronian Supergroup of the Sudbury District has been acknowledged for decades (Innes and Colvine 1979)(*see also* Figure 2). The proposed mechanism of emplacement of these deposits is modelled after the world-class Witwatersrand placer deposits in South Africa (Mossman and Harron 1983). Using the sedimentation history compiled by Fralick and Miall (1981) in their paleoplacer uranium deposit study (Figure 3), Mossman and Harron (1984) suggested that the Lorrain and Mississagi formations would be the most suitable sedimentary environment for the development and preservation of paleoplacer gold mineralization with minimal uranium enrichment. These formations are interpreted to be fluvial to nearshore to shallow-marine sedimentary environments. They are characterized by conglomerate layers and sections of reverse-graded sediments. Known paleoplacer gold occurrences are most commonly

Gold in the Huronian Supergroup, Sudbury District

found within pyritic conglomerate beds, although other sedimentary facies may also contain anomalous gold (Mossman and Harron 1984). In Figure 2, the Lorrain and Mississagi formations are indicated as prospective areas for paleoplacer gold exploration. The Ontario Mineral Deposit Inventory (Ontario Geological Survey 2017) gold occurrences in the Sudbury District are also shown on Figure 2. Many of the records do not include deposit classification, and only a small number are classified as paleoplacer. However, Table III of Mossman and Harron (1984) lists a compilation of 31 stratiform gold deposits in the Huronian Supergroup which have been interpreted to be of paleoplacer type (Table 1). Of these, 21 were found in the current Ontario Mineral Deposit Inventory (Ontario Geological Survey 2017), and 20 appear on Figure 2. Sedimentological and depositional facies analysis, seeking the conglomerate beds and evidence for fluvial or paleochannel sediments, can be an effective exploration tool for targeting the search for paleoplacer gold deposits in the Huronian Supergroup.

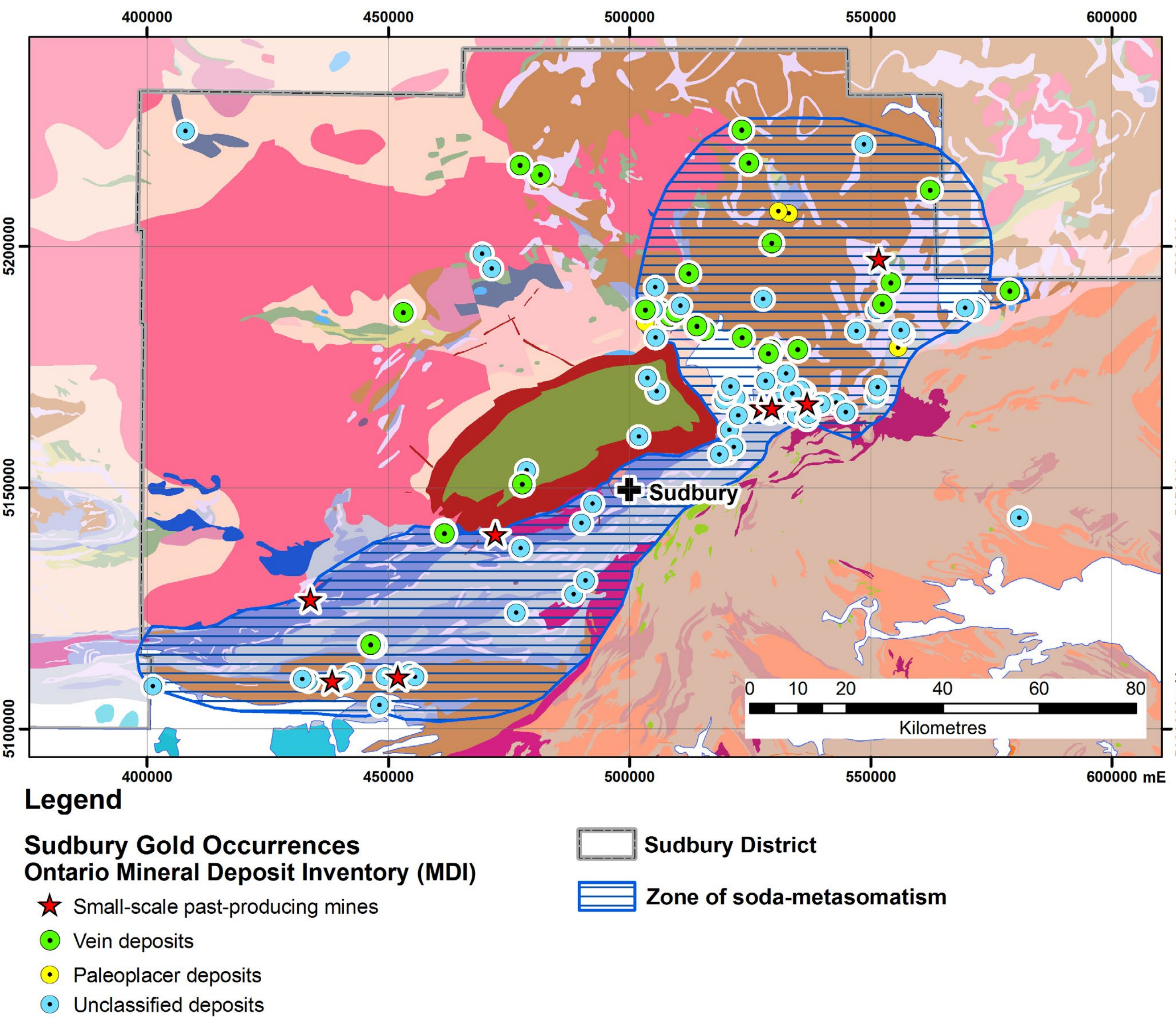

Figure 1. Sudbury District showing gold occurrences from the Ontario Mineral Deposit Inventory (Ontario Geological Survey 2017), and the area of interest for soda-metasomatized, possibly IOCG, deposits. Geology *from* Ontario Geological Survey (2011); Universal Transverse Mercator (UTM) co-ordinates are provided using North American Datum 1983 (NAD83) in zone 17.

Gold in the Huronian Supergroup, Sudbury District

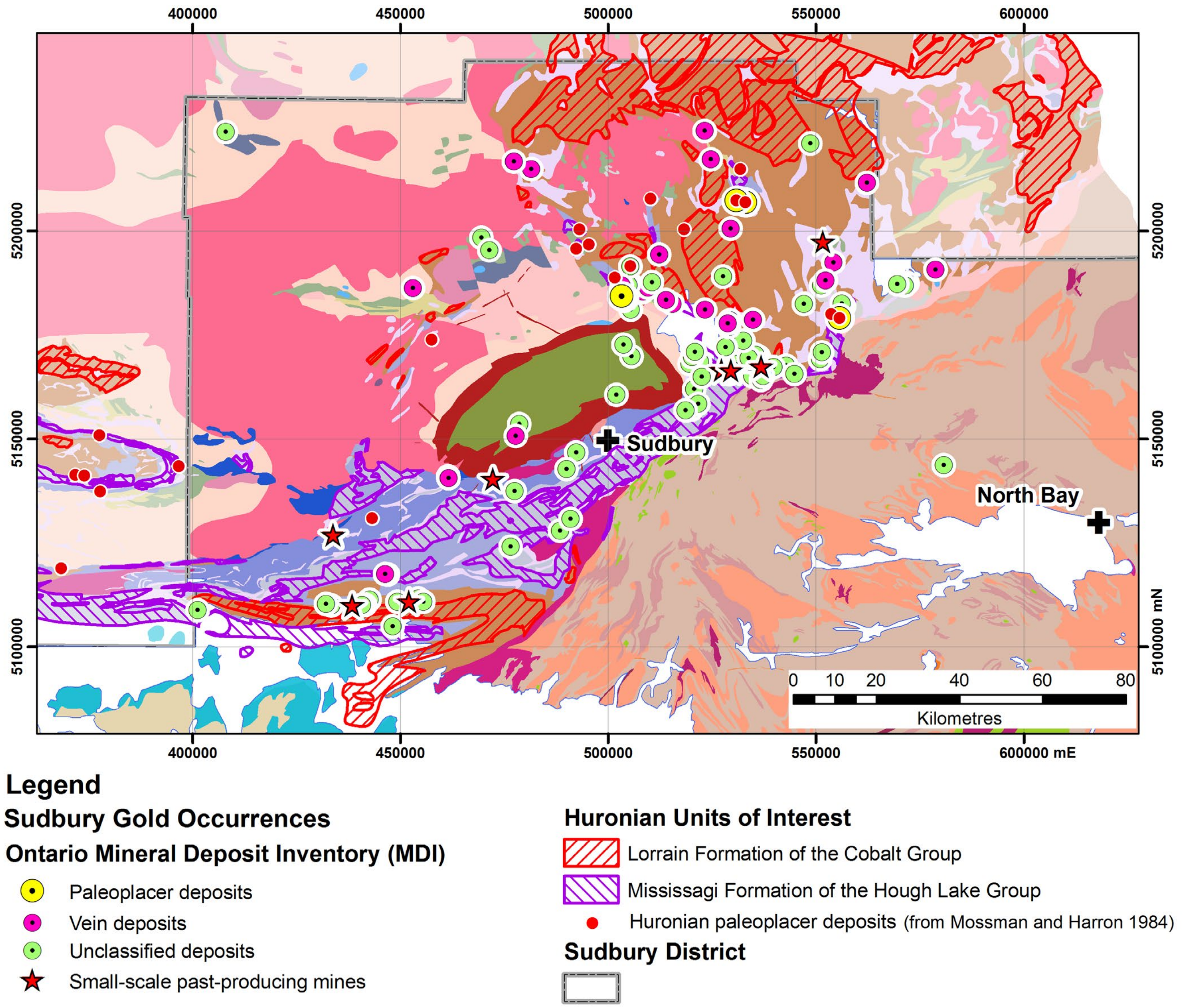

Figure 2. Geology of the Sudbury District showing gold occurrences from the Ontario Mineral Deposit Inventory (Ontario Geological Survey 2017) and the area of interest for paleoplacer gold deposits: the Lorrain Formation of the Cobalt Group and Mississagi Formation of the Hough Group. Geology *from* Ontario Geological Survey (2011); UTM co-ordinates are provided using NAD83 in zone 17.

Gold in the Huronian Supergroup, Sudbury District

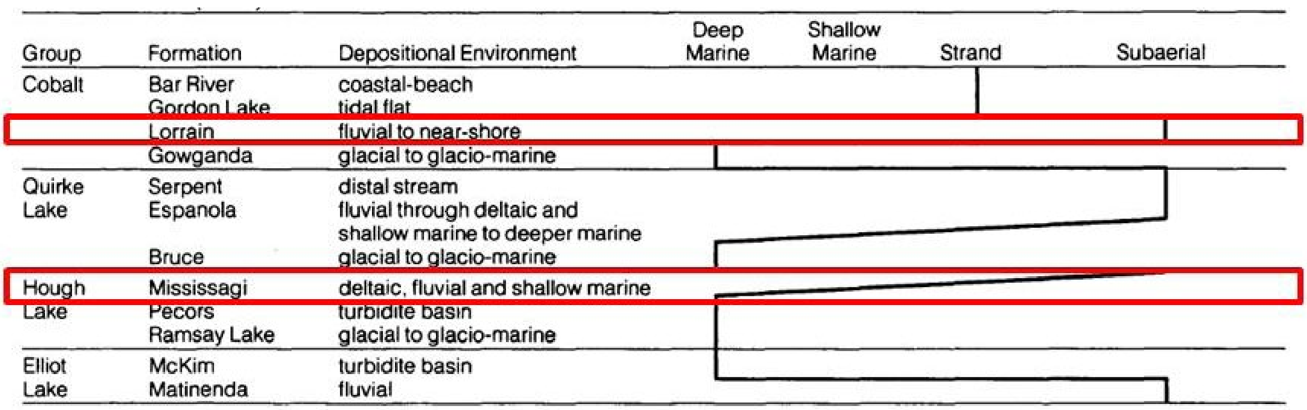

Figure 3. The sedimentation history of the Huronian Supergroup compiled by Fralick and Miall (1981), showing fluctuating depositional environments ranging from deep marine to beach to subaerial deposits. The Lorrain and Mississagi formations (outlined in red) of the Cobalt and Hough groups, respectively, are considered to be the most prospective for paleoplacer gold deposition, according to Mossman and Harron (1984).

Table 1. Occurrences of stratiform (paleoplacer) gold or gold-uranium throughout the Huronian Supergroup. Occurrences in bolded text appear on Figure 2. Occurrences marked with a pound symbol (#) do not appear on Figure 2, and those marked with a single asterisk (*) were not found in the Mineral Deposit Inventory (Ontario Geological Survey 2017). Table *modified from* Mossman and Harron (1984, Table III).

Occurrence Name	Township	Formation	RGP District
#Corbold Lake	Montgomery	Bruce	Sault Ste. Marie
*Picton U	Jogues	Mississagi	Sault Ste. Marie
Pronto	**Long**	**Matinenda**	**Sault Ste. Marie**
Denison	**Bouck**	**Malinenda**	**Sault Ste. Marie**
Silvermaque	**Gunterman**	**Bruce and Mississagi**	**Sault Ste. Marie**
Nordic	**Gunterman**	**Matinenda**	**Sault Ste. Marie**
Stanleigh	**Gunterman**	**Matinenda**	**Sault Ste. Marie**
B.C. Explor. #2	**Gaiashk**	**Matinenda**	**Sault Ste. Marie**
Cons. Monclerg	**Baldwin**	**Mississagi**	**SUDBURY**
Hess Lake	**Hess**	**Espanola**	**SUDBURY**
Roberts Lake	**Roberts**	**"Mississagi"**	**SUDBURY**
Nordic	**Roberts**	**"Mississagi"**	**SUDBURY**
Leslie	**Creelman**	**"Mississagi"**	**SUDBURY**
*North Hutton	Hutton	"Mississagi"	SUDBURY
*Central Hutton	Hutton	"Mississagi"	SUDBURY
Banagan Lake	**Hutton**	**"Mississagi"**	**SUDBURY**
C.J.M.	**Grigg**	**"Mississagi"**	**SUDBURY**
*Flesher Lake	Parkin	"Mississagi"	SUDBURY
Powertine Rd.	**Parkin**	**Serpent****	**SUDBURY**
*Bouma	Parkin	"Mississagi"	SUDBURY
*C.J.M.	Stobie	"Mississagi"	SUDBURY
T. Saville	**Turner**	**"Mississagi"**	**SUDBURY**
T. Saville	**McNish**	**"Mississagi"**	**SUDBURY**
Pickle Crow - Pardo	**Pardo**	**"Mississagi"**	**SUDBURY**
*Wright	Vogt	"Mississagi"	SUDBURY
Inco DOH #54060	**Telfer**	**"Mississagi"**	**SUDBURY**
Inco DOH #54061	**DeMorest**	**Serpent and "Mississagi"**	**SUDBURY**
Inco DOH #54062	**DeMorest**	**"Mississagi"**	**SUDBURY**
	Lundy (North Half)	Lorrain	Kirkland Lake
	Dufferin and North Williams	Lorrain	Kirkland Lake
*Cultis Lake	Day	Thessalon	Sault Ste. Marie

Note from *Mossman and Harron (1984): "the occurrences placed in "'Mississagi" may possibly be from the Elliot Lake Group (D.G.F. Long–pers. comm.)"*
*** probably "Mississagi".*

Gold in the Huronian Supergroup, Sudbury District

REFERENCES

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

Fralick, P.W. and Miall, A.D. 1981. Sedimentology of the Matinenda Formation; *in* Geoscience Research Grant Program, Summary of Research, 1980–1981, Ontario Geological Survey, Miscellaneous Paper 98, p.80-89.

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

Gordon, J.B., Lovell, H.L., de Grijs, J. and Davie, R.F. 1979. Gold deposits of Ontario, Part 2: Part of District of Cochrane, Districts of Muskoka, Nipissing, Parry Sound, Sudbury, Timiskaming, and Counties of Southern Ontario; Ontario Geological Survey, Mineral Deposits Circular 18, 253p.

Innes, D.G., and Colvine, A.C.1979. Metallogenetic development of the eastern part of the Southern Province, Ontario; *in* Summary of Field Work, 1971, Ontario Geological Survey, Miscellaneous Paper 90, p.184-189.

Mossman, D.J. and Harron, G.A. 1983. Origin and distribution of gold in the Huronian Supergroup, Canada – the case for Witwatersrand-type paleo-placers; Journal of Precambrian Geology, v.20, p.543-583.

——— 1984. Witwatersrand-type paleo-placer gold in the Huronian Supergroup of Ontario, Canada; Geoscience Canada, v.11, p.33-40.

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

——— 2017. Mineral Deposit Inventory; Ontario Geological Survey, Mineral Deposit Inventory, online database.

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

Williams, P.J., Barton, M.D., Johnson, D.A., Fontbote, L., de Haller, A., Mark, G., Oliver, N.H.S. and Marschik, R. 2005. Iron ioxide-copper-gold deposits: Geology, space-time distribution, and possible modes of origin; Economic Geology, 100th Anniversary Volume, p.371-406.

HIGHLIGHTS

- Getting back to basics for target generation.
- Key criteria for regional gold exploration targeting.
- Idealised structural configurations within a greenstone belt as gold targets.
- Areas of sizeable granitoid emplacement, especially near intrusive contacts adjacent to favourable greenstone rock types, should be considered.

Gold – Getting Back to Basics

They say gold is where you find it, and sadly, most, if not all, of the easy pickings have already been discovered, thus making future discoveries a little more challenging! Future discoveries will require visiting areas not previously flagged as "prospective", and will invariably be in areas where bedrock is hidden under cover, a swamp or lake, and where access is poor or difficult.

In getting back to the basics for target generation, the explorationist is referred to an excellent compilation and assessment on the structural controls of gold mineralization in the Zimbabwe Craton (Campbell and Pitfield 1994), which was not only based on extensive field work and structural mapping, both on surface and underground, but draws on similar analogs from the Yilgarn of Western Australia (Groves et al. 1988) and locally here within the Abitibi (Colvine et al. 1984). Key criteria for gold exploration targeting are summarized in Table 1 and presented graphically in Figure 1.

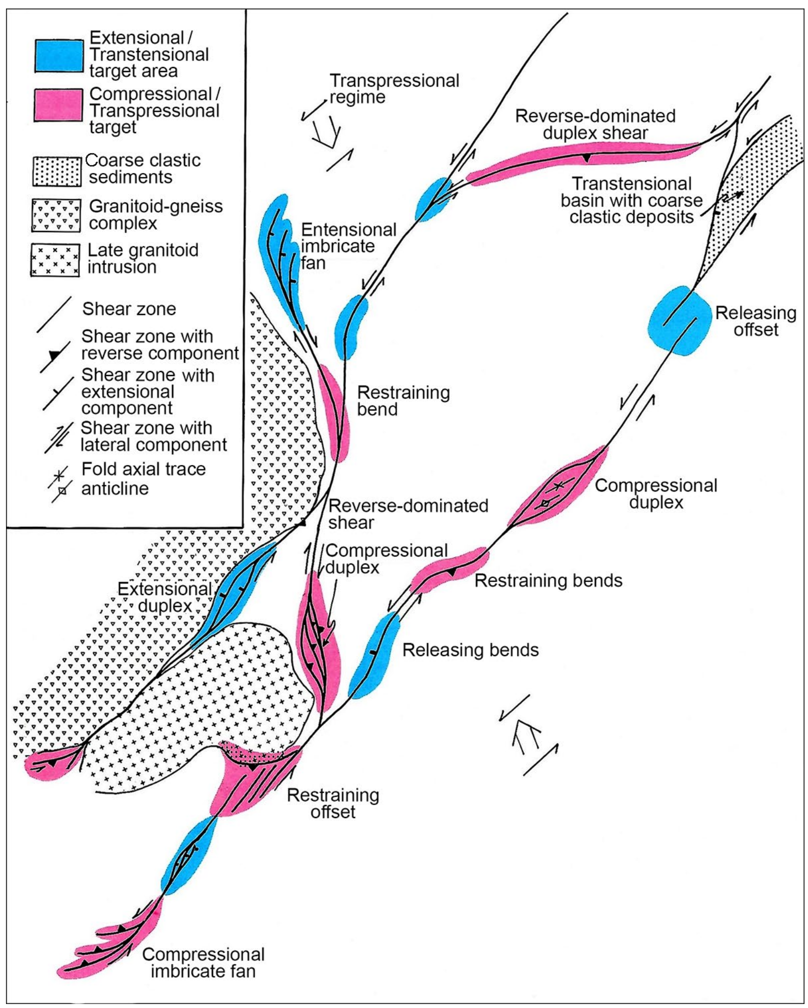

Figure 1. Idealised structural configurations associated with shear zones and faults within a greenstone belt, with potential target areas for gold mineralization highlighted (*modified from* Campbell and Pitfield 1994).

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Gold – Getting Back to Basics

Table 1. Key criteria for regional gold exploration targeting (*modified from* Campbell et al. 1994).

Targeting Shear Zones and Faults	Targeting Folds	Targeting Related to Granitoid Plutons
Consider structurally anomalous segments: • Pronounced inflections in shear or fault • Splays from main shear zone • Intersections of individual shears and faults • Imbricate splays at shear ends • *En échelon* segmentation and duplexes • Folding within or adjacent to shear Consider specific rock types and lithological contrasts in, or adjacent to, shears: • Proximity of shear to margin of a granitoid pluton within the greenstone belt • Alternating felsic and greenstone rock types (especially their contacts) • Banded iron formation, both within and adjacent to shear zone • Ultramafic rock types (especially where in contact with granitoid gneiss – where basement rocks are present) • Areas of clastic rocks associated with shear zones	Consider the following, in particular: • Fold noses and associated axial shearing • Limb shearing and fold asymmetry • Associations of fold axes with felsic, synvolcanic intrusions • Folding of interbedded felsic rocks, banded iron formation or greenstones • Fold axial traces parallel to nearby granitoid margins	Emphasis to be given to the following: • Contacts between rocks with contrasting competency striking subparallel to granite margins • Radial faults or shear zones relative to granite contact • Concentric arrays of felsic intrusions near a granitoid

A geological map of the Kirkland Lake District (Ontario Geological Survey 2011) is shown in Figure 2, showing the locality of gold projects with a published gold resource exceeding 250 000 ounces (based on news releases and statutory reports as compiled by the Kirkland Lake Resident Geologist office), as well as all Mineral Deposit Inventory (MDI) data pertaining to gold as a primary commodity (Ontario Geological Survey 2017). Furthermore, a broad target area has been highlighted based on proximity to favourable lithological contacts, geological structures and other criteria described by Wilson et al. (2008).

The explorationist is urged to look carefully at Figure 2, taking cognisance of the key criteria and structural configurations presented above. The localities of projects with notable published gold resources, in addition to point localities where the presence of gold as a primary commodity has been noted (based on MDI data), will also assist in looking for areas within the district that may be amenable for further gold exploration.

Lastly, areas of sizeable granitoid emplacement (the various syntectonic batholiths as indicated in Figure 2), have long been dismissed as exploration targets – but needn’t have been, especially in areas proximal to the intrusive contact adjacent to a favourable greenstone lithology. A similar study relating to structural styles and potential gold targets is presented by Guindon et al. (2010), the approach being slightly different, but well worth a re-visit.

Gold – Getting Back to Basics

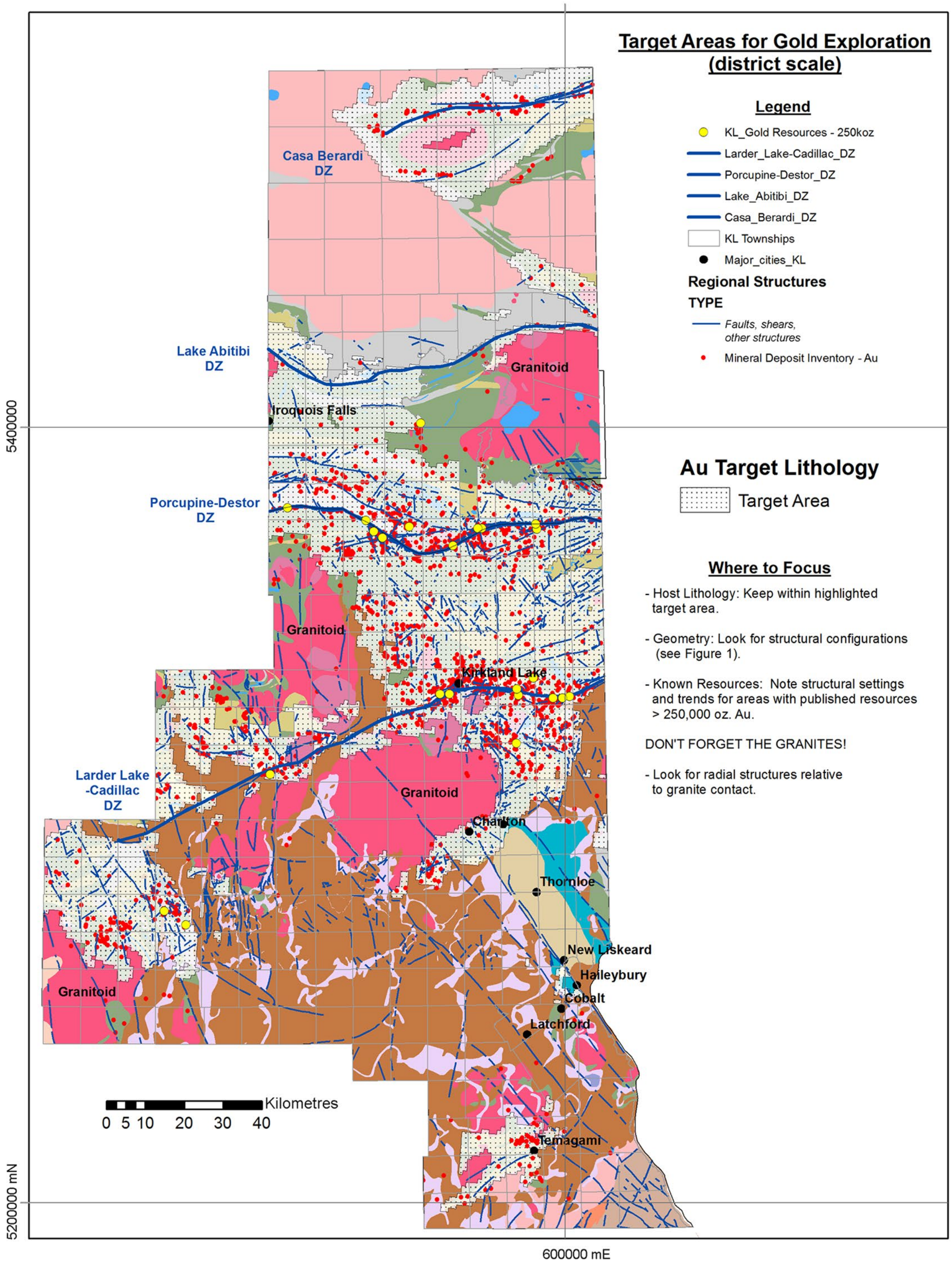

Figure 2. Geological map of the Kirkland Lake District, highlighting areas of preferred host rock lithology, major geological structures and clues as to where to explore for gold. Geology *from* Ontario Geological Survey (2011). Abbreviations: DZ, deformation zone; KL, Kirkland Lake. Universal Transverse Mercator (UTM) co-ordinates are provided using North American Datum 1983 (NAD83) in Zone 17.

Gold – Getting Back to Basics

REFERENCES

Campbell, S.D.G. and Pitfield, P.E.J. 1994. Structural controls of gold mineralization in the Zimbabwe Craton – Exploration guidelines; Zimbabwe Geological Survey, Bulletin 101, 270p.

Colvine, A.C., Andrews, A.J., Cherry, M.E., Durocher, M.E., Fyon, A.J., Lavigne, M.J., MacDonald, A.J., Marmont, S., Poulsen, K.H., Springer, J.S. and Troop, D.G. 1984. An integrated model for the origin of Archaean lode-gold deposits; Ontario Geological Survey, Open File Report 5524, 98p.

Groves, D.I., Ho, S.E., McNaughton, N.J., Mueller, A.G., Perring, C.S., Rock, N.M.S. and Skwarnecki, M.S. 1988. Genetic models for Archaean lode-gold deposits in Western Australia; *in* Advances in Understanding Precambrian Gold Deposits, Volume II, Geology Department and University Extension, University of Western Australia, Publication no.12, p.1-22.

Guindon, D.L., Grabowski, G.P.B., Wilson, A.C. and van Zeyl, D.P. 2010. Report of Activities 2009, Resident Geologist Program, Kirkland Lake Regional Resident Geologist Report: Kirkland Lake District; Ontario Geological Survey, Open File Report 6248, 54p.

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

——— 2017. Mineral Deposit Inventory 2017, Ontario Geological Survey, online database.

Wilson, A.C., Rowell, D.J., Seim, G. Wm. and Debicki, R.L. 2008. Procedural guidelines for provincially significant mineral potential assessments; Ontario Geological Survey, Open File Report 6141, 91p.

HIGHLIGHTS

- **Gold-rich volcanogenic massive sulphides in the Blake River Assemblage.**
- **Base-metal and gold occurrences discovered in Ben Nevis Township.**
- **Promising drill-hole and grab-sample assay results.**
- **Excellent structural framework.**
- **Ben Nevis Township not sufficiently explored.**

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Volcanogenic Massive Sulphide Deposits in Ben Nevis Township: Are We Missing Something?

The Blake River Assemblage (BRA) is the youngest volcanic sequence in the Abitibi greenstone belt (Ross et al. 2007), the largest greenstone belt in the world. Of all the Archean sequences in the Abitibi greenstone belt, the BRA contains the most abundant concentration of volcanogenic massive sulphide (VMS) deposits. Approximately half of the total VMS tonnage of the Abitibi greenstone belt is located in the BRA, and about 90% of the total "VMS gold" in the belt is found in the BRA. The Rouyn-Noranda mining district on the Quebec side of the provincial border contains some of the most thoroughly studied and documented VMS deposits of any Archean volcanic complex. The central camp of the Rouyn-Noranda mining district is best known for its massive sulphide deposits. These deposits are hosted by effusive basalt and basaltic andesite flows and subordinate rhyolite flow–dome complexes. However, the bulk of the production in the district originate from massive sulphide deposits hosted by felsic rock successions dominated by volcaniclastic rocks (Mercier-Langevin et al. 2011).

Ben Nevis Township lies within the Upper BRA in the Kirkland Lake District, Larder Lake mining division of Ontario. The Ben Nevis–Clifford township area was initially investigated by W.J. Wilson (1901), followed by reconnaissance mapping by C.W. Knight in 1919 (Knight 1920) and T.L. Gledhill in 1927 (Gledhill 1929). Peter Roche and E.O. Ehrhart discovered several small base-metal and gold occurrences in the township, after the discovery of gold in Larder Lake in 1906. Later studies of the area reported on the volcanology, stratigraphy and geochemistry (Baragar 1968); mineralization and volcanic stratigraphy (Ridler 1970); the relationship between the volcanic and intrusive rocks (Jolly 1977); and the lithogeochemistry (Grunsky 1986, 1988). More recent studies include the geology and base-metal mineralization (Péloquin and Piercey 2005) and volcanic stratigraphy (Péloquin, Piercey and Hamilton 2008) of the area. Ben Nevis is underlain dominantly by intermediate and felsic metavolcanic rocks of Archean age that are intruded by dikes and sills of mafic, intermediate and felsic composition. An early, regional, northeast-striking fault—the Murdock Creek–Kennedy Lake (MCKL) fault (Figure 1)—is the most prominent structural feature in Ben Nevis Township. It extends into Pontiac Township, to the immediate east, and bifurcates into Clifford Township, to the west. A north-striking fault is located in the southeast corner of the township. Jensen (1975) stated that local faults are radial and "circular" tension faults, related to the felsic intrusive complex in Clifford Township. They strike northwest and northeast in the northern and southern halves, respectively, of Ben Nevis Township, and are cut off by the regional fault.

The main rock types in the township consist of intermediate metavolcanic, felsic metavolcanic, mafic intrusive and felsic to intermediate intrusive rocks. Both pyroclastic and flow facies occur in all rock types, but the felsic metavolcanic rocks are dominantly pyroclastic. Andesite flows are the dominant rock type in the township (Péloquin,

VMS Deposits in Ben Nevis Township: Are We Missing Something?

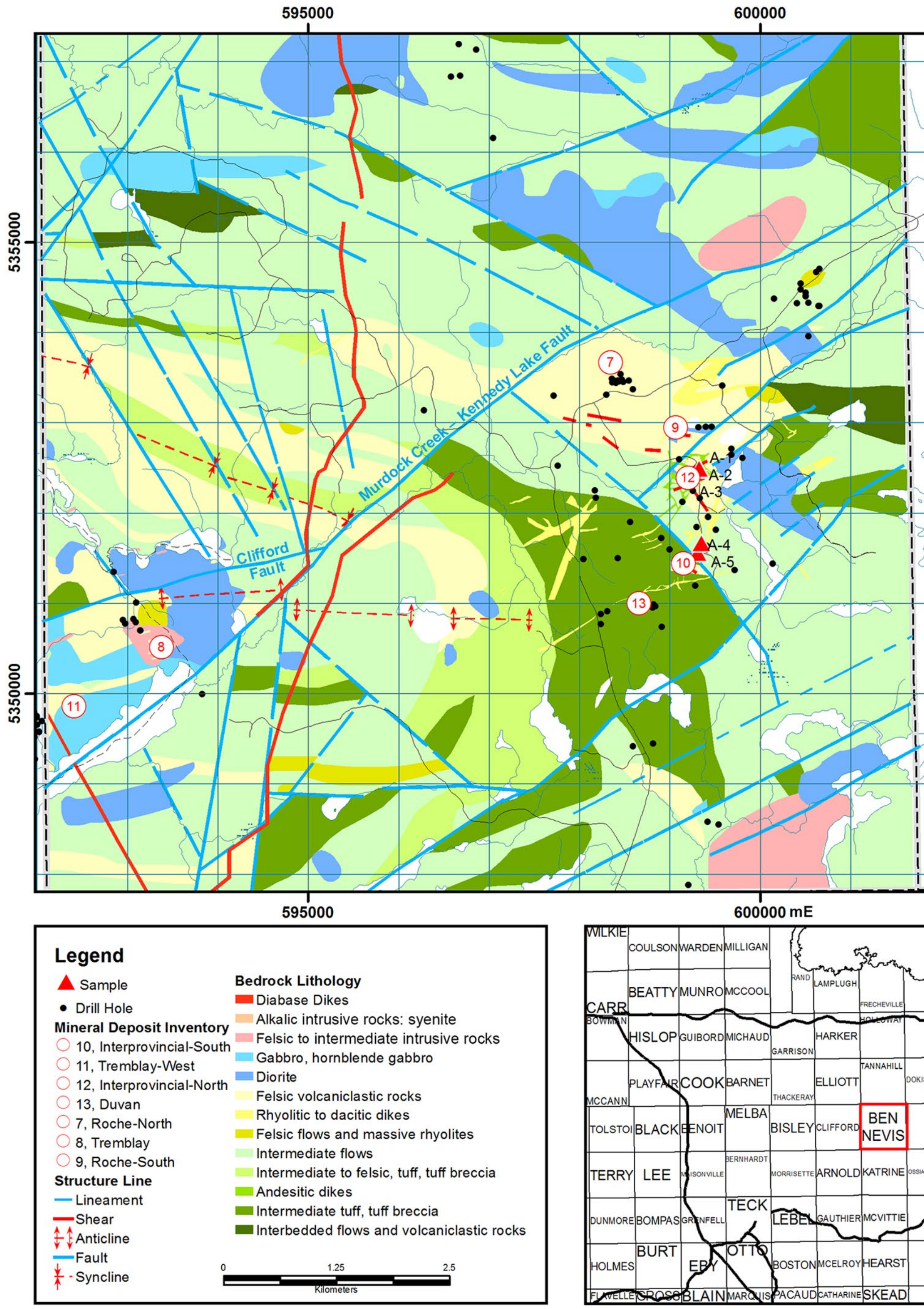

Figure 1. Geological map of Ben Nevis Township showing historic drill-hole localities, mineral deposits and occurrences (source: Mineral Deposit Inventory database (Ontario Geological Survey 2017)) and sample localities listed in Table 1. Geology *modified from* Peloquin (2005). Universal Transverse Mercator (UTM) co-ordinates are provided using North American Datum 1983 (NAD83) in zone 17.

VMS Deposits in Ben Nevis Township: Are We Missing Something?

Piercey and Hamilton 2008; Péloquin and Piercey 2005). Most of the felsic and intermediate metavolcanic outcrops stripped by previous explorers display patchy to pervasive carbonate and sericitic alteration, with local rusty-coloured stains and surfaces (Photo 1A). Pyrite is the most common sulphide mineral occurring in the metavolcanic and intrusive rocks, but galena, chalcopyrite, bornite, sphalerite, arsenopyrite, silver and gold are present in intermediate and felsic metavolcanic rocks in a range of geological settings. For example, at the Duvan occurrence (*see* Figure 1), in the southeastern part of Ben Nevis Township, the sericitic and iron-carbonate–altered andesitic outcrop shows vesicular quartz flooding and chert nodules up to 4 cm wide. The mineralization consists of fine-grained, euhedral (up to 1 mm) cubes of pyrite and arsenopyrite occurring as semi-massive to massive patches (Photo 1C). Diamond drilling in the township presented encouraging results; for example, in 1964 Frobex Limited intersected a shear zone on the Roche-South property located in the east-central part of Ben Nevis Township (*see* Figure 1). In diamond-drill hole F64-1, the shear zone was found to contain 94.3 g/t silver, 0.53% lead and 1.95% zinc over 7.1 m. Drill hole F64-6 yielded 43.2 g/t gold, 0.08% lead and 0.25% zinc over 3.3 m (Jensen 1975, AFRI 32D05SE0070). Table 1 shows encouraging assay results for grab samples collected by the author from several localities.

Ben Nevis Township has the potential to host gold-rich VMS deposits comparable to those in the Rouyn-Noranda mining district. It could be argued, from looking at the number and cluster of historic drill holes and mineral occurrences in Figure 1, that the eastern and southwestern halves of Ben Nevis Township have undergone some

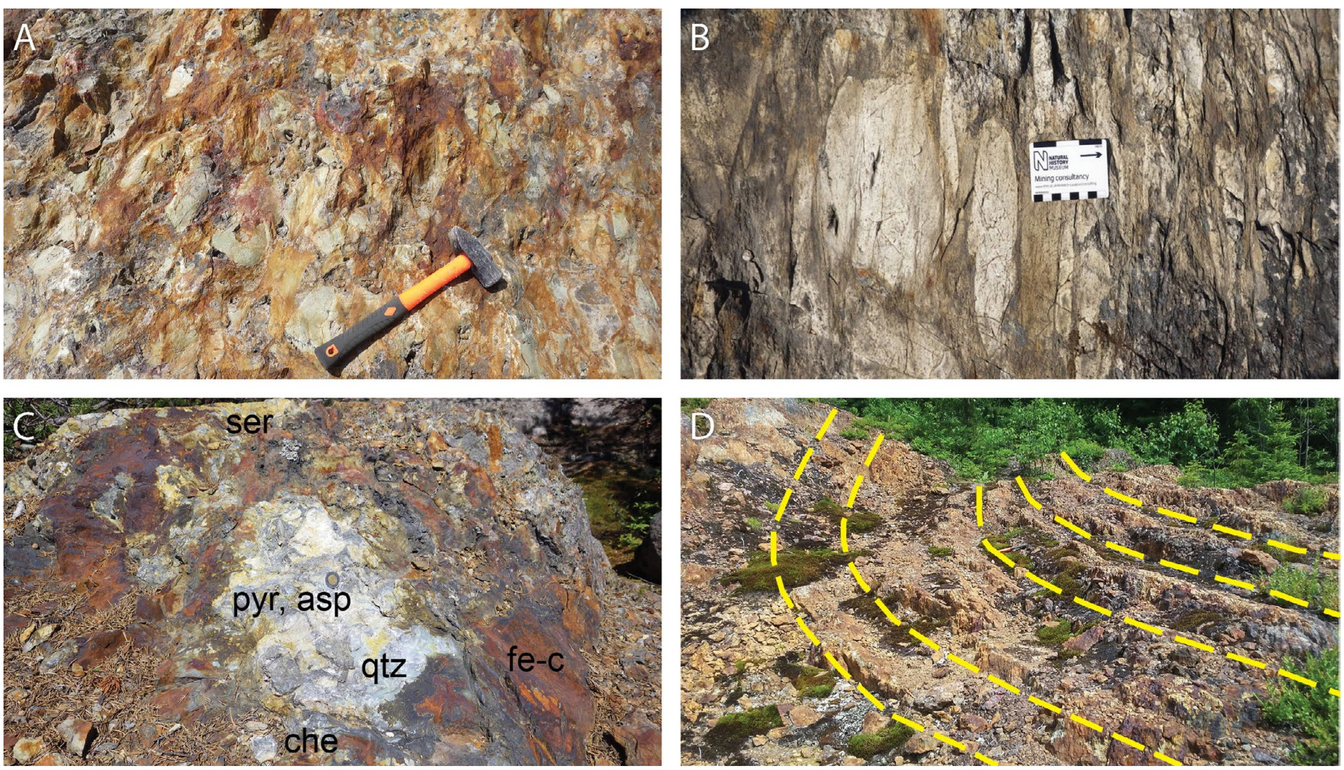

Photo 1. A) Carbonate-altered rhyodacitic rock with sulphide staining, stretched lobes and breccia fragments. Looking northwest. Hammer is 30 cm long. 598265E 5353599N, zone 17; Roche-North property, northeast quadrant of Ben Nevis Township. Compare with **B)** Rhyodacitic outcrop with lobes and breccia at the LaRonde Penna Mine, Quebec. Looking west. It represents the footwall of the mineralized sulphide lens located at 800 m below the surface. **C)** Altered andesitic rock with chert nodules, quartz flooding and sulphide mineralization. ser = sericite, fe-c = iron-carbonate, che = chert, qtz = quartz, pyr = pyrite, asp = arsenopyrite. Two dollar coin in centre of photo for scale; 598437E 5350931N, zone 17; looking east. Duvan occurrence in southeast Ben Nevis Township. **D)** Radial structures in brecciated rock. Looking east. Hammer (30 cm long) in centre of photo for scale. 599242E 5352332N, zone 17; Interprovincial-North property, Ben Nevis Township.

VMS Deposits in Ben Nevis Township: Are We Missing Something?

appreciable mineral exploratory work. In addition, a number of outcrop showings, historic shafts and trenches were encountered in the field by the author. These facts raise the question: "Why are there no producing mines in the township?" A plausible response might include "exploration remains incomplete within the township". More rigorous follow-up exploration in the form of deep-hole diamond drilling, focussing on structurally favourable targets to penetrate cover to intersect prospective underlying rocks hosting VMS deposits, is recommended for the eastern half of the township. Particular attention should be given to observing and recording subtle ore-controlling structures, in addition to noting alteration indices that might aid in the delineation of, and establish the proximity to, target exhalite-rich zones.

Furthermore, excluding the area between the southwestern extension of the MCKL fault and the Clifford fault to the north, the western half of the township is relatively unexplored, despite the presence of potentially favourable structures. It is postulated that the northwest-trending, parallel faults to the north of the MCKL fault and the north-northeast and northeast, crosscutting faults to the south of the MCKL fault are synvolcanic. These faults could have focused hydrothermal fluid flow, and where they crosscut one another or where they truncate one another, lithologic units may be favourable sites for massive sulphide deposition. Further, the andesite dikes and the rhyolite to dacitic dikes illustrated in Figure 1 may also have been emplaced along synvolcanic faults. Careful attention to tops indicators, like flow-top breccia and pillow structures, may assist in the delineation of synvolcanic faults through stratigraphy and lead to the identification of other favourable locations for sulphide deposition.

Finally, the presence of radial structures (Photo 1D) may signify feeder structures of a nearby VMS edifice, and should not be overlooked. At the Millenbach and D-68 deposits in the Noranda mining camp, a feeder dike defines the trace of the South Rusty Hill fault, a northeast-striking, radial (synvolcanic) fault (Watkinson 1991).

Table 1. Location and assay results of selected grab samples collected from Ben Nevis Township, Kirkland Lake District.

Sample ID	Zone 17, NAD83		Gold (g/t)	Silver (g/t)	Copper (%)	Lead (%)	Zinc (%)	Property	Field Notes
	Easting	Northing							
A-1	599336	5352485	6.50	15.63	0.08	0.36	2.69	Roche-South	Samples collected from a brown-orange, sulphide-stained outcrop. Altered andesite/basalt? Mineralization related to sets of joints: 130° to 136°/80°S truncate younger joints of 046° to 050°/42°S to 52°S.
A-2	599328	5352496	2.00	346.90	0.06	4.02	5.24	Roche-South	
A-3	599220	5352446	<0.50	<3.12	0.22	1.02	6.06	Interprovincial-North	Collected 5 m northwest of shaft #2. Semi-massive galena and black, opaque, tetrahedral crystals of sphalerite present in altered rock (andesite?)
A-4	599314	5351560	0.59	34.38	0.02	3.36	1.53	Interprovincial-South	Strongly carbonate-altered rhyodacitic sample with semi-massive zinc, pyrite and arsenopyrite. Collected from east-west-trending trench (10 m long, 3 m wide, and 3 m deep). Surface of surrounding outcrop shows curved or radial faults or "shells" at 112°/80°S, 70°/76°S and 88°/82°S, with pyrite and galena mineralization occurring as veinlets and along fractures.
A-5	599355	5351670	3.44	15.62	0.04	0.29	2.28	Interprovincial-South	Collected from a sheared andesitic outcrop 260° to 300° with near vertical dips. Cross fractures oriented at 210° to 258° with 8° to 20°S dips. Semi-massive pyrite mineralization.

VMS Deposits in Ben Nevis Township: Are We Missing Something?

REFERENCES

Baragar, W.R.A. 1968. Major-element geochemistry of the Noranda volcanic belt, Québec-Ontario; Canadian Journal of Earth Sciences, v.5, p.773-790.

Gledhill, T.L. 1929. Ben Nevis, Munro, Kamiskotia and other base metal areas, Districts of Cochrane and Timiskaming; Ontario Department of Mines, v.37, pt.3, p.1-52.

Grunsky E. 1988. Multivariate and spatial analysis of lithogeochemical data from metavolcanics with zones of alteration and mineralization in Ben Nevis Township, Ontario; unpublished PhD thesis, University of Ottawa, Ottawa, Ontario, 710p.

——— 1986. Recognition of alteration and compositional variation patterns in volcanic rocks using statistical analysis of lithogeochemical data, Ben Nevis Township area, District of Cochrane, Ontario; Ontario Geological Survey, Open File Report 5628, 187p.

Jensen, L.S. 1975. Geology of Clifford and Ben Nevis townships, District of Cochrane; Ontario Division of Mines, Geological Report 132, 55p.

Jolly, W.T. 1977. Relations between Archean lavas and intrusive bodies of the Abitibi greenstone belt, Ontario–Quebec; *in* Volcanic Regimes in Canada; Geological Association of Canada, Special Paper 16, p.311-330.

Knight, C.W. 1920. Ben Nevis gold area; Ontario Department of Mines, v.29, pt.3, p.1-27.

Mercier-Langevin, P., Goutier, J., Ross, P.-S., McNicoll, V., Monecke, T., Dion, C., Dubé, B., Thurston, P., Bécu, V., Gibson, H., Hannington, M. and Galley, A. 2011. The Blake River Group of the Abitibi greenstone belt and its unique VMS and gold-rich VMS endowment; Geological Survey of Canada, Open File 6869, 61p.

Ontario Geological Survey 2017. Mineral Deposit Inventory; Ontario Geological Survey, Mineral Deposit Inventory, online database.

Péloquin, A.S. 2005. Precambrian geology of Ben Nevis and Katrine townships; Ontario Geological Survey, Preliminary Map P.3543—Revised, scale 1:20 000.

Péloquin, A.S. and Piercey, S.J., 2005. Geology and base metal mineralization in Ben Nevis, Clifford and Katrine townships: Discover Abitibi Initiative; Ontario Geological Survey, Open File Report 6161, 86p.

Péloquin, A.S., Piercey, S.J. and Hamilton, M.A. 2008. The Ben Nevis volcanic complex, Ontario, Canada: Part of the late volcanic phase of the Blake River Group, Abitibi Subprovince; Economic Geology v.103, p.1219-1241.

Ridler, R.H. 1970. Relationship of mineralization to volcanic stratigraphy in the Kirkland–Larder Lakes area, Ontario; *in* Proceedings, Geological Association of Canada, Winnipeg, Manitoba, v.21, p.22-42.

Ross, P.-S., Percival, J.A., Mercier-Langevin, P., Goutier, J., McNicoll, V.J. and Dubé, B. 2007. Intermediate to mafic volcaniclastic units in the peripheral Blake River Group, Abitibi Greenstone Belt: Origin and implications for VMS exploration; Geological Survey of Canada, Current Research 2007-C3, 25p.

Watkinson, D.H. 1991. Mineral deposits of Noranda, Quebec and Cobalt, Ontario (Field Trip 4); Geological Survey of Canada, Open File 2159, 52p.

Wilson, W.J. 1901. Western part of the Abitibi region; *in* Geological Survey of Canada, Summary Report, Part A, v.14, p.H7A-130A.

Geochemistry of Volcanogenic Massive Sulphide Deposits

HIGHLIGHTS

- **Many volcanogenic massive sulphide (copper-zinc) deposits in Ontario are potential sources of cobalt.**
- **7 of 27 VMS samples analyzed averaged cobalt concentrations of 1741 ppm (approx. value US$115/t).**
- **VMS deposits might also be a source of cadmium, selenium, tin, titanium, tellurium and vanadium.**

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SUMMARY

Analysis of 27 volcanogenic massive sulphide (VMS) copper-zinc samples produced high Cu, Pb and Zn assays as well as high concentrations of Ag, Au and Co. The concentration of accessory Ag, Au and Co in some samples might impact the economic viability of deposits being explored. Given this development, the geochemistry of massive sulphide deposit mineralization should be fully characterized to ensure a complete economic assessment.

The cobalt concentration in 7 of 27 VMS samples analyzed averaged 1741 ppm (1.74 kg/t or 3.8 lbs/t) and is currently worth just under US$115/t.

Bornite and galena samples from the Kidd Creek Mine both contained more than 50 ounces of silver per tonne, an amount that greatly exceeds the average silver content of just over 1 ounce per tonne for the other 25 samples (2 Kidd Creek samples excluded). The high silver content suggests VMS deposits containing bornite and galena warrant special attention.

INTRODUCTION

Published geochemical data for VMS deposits typically include results on Cu, Zn, Pb, Ag and Au (Franklin and Thorpe 1982). Unpublished data indicate some massive sulphide deposits contain other elements that might be of economic importance. Cobalt has been documented in a number of VMS deposits, including Genex (van Hees, unpublished data), Kidd Creek (Gemmell 2013), and Potter mines (D. Gamble, personal communication, August 2017). Cobalt assays of 1000 to 1500 ppm in these 3 deposits are equivalent to 2 to 3 pounds per tonne of rock and valued between US$60 to US$90 (at US$29.65 per lb., Table 1). The Kidd Creek Mine has also produced up to 60 tonnes of selenium per year (Gemmell 2013).

Table 1. Value of metals (October 5, 2017).

Element	US$/g	Element	US$/lb	Element	US$/lb
Ag	0.54	**Bi**	4.68	**Pb**	1.17
Au	41.05	**Cd**	0.88	**Sb**	3.71
Ir	21.70	**Co**	29.65	**Se**	26.00
Pd	29.61	**Cr**	3.40	**Sn**	9.45
Pt	29.29	**Cu**	3.83	**Te**	14.55
Rh	35.85	**Mo**	7.26	**78%Ti**	16.82
		Ni	4.83	**V_2O_5**	22.10

Source of Metal Prices:
Ag, Au, Pd, Pt, Rh – Kitco.com; Cu, Mo, Ni, Pb, Zn – London Metals Exchange
Cd, Ir, Se, V2O5 – Northern Miner; Bi, Co, Cr, Sb, Sn, Te, 78%Ti – Metalbulletin.com

Geochemistry of Volcanogenic Massive Sulphide Deposits

Elements analyzed on about 100 massive sulphide samples collected and submitted to Geoscience Laboratories (GeoLabs) in Sudbury (including the 27 VMS samples in this Recommendation for Exploration and the 17 copper-nickel, Sedex and Other samples in Recommendation 9: "Geochemistry of Copper-Nickel, Sedex and Other Massive Sulphide Deposits") will provide a broad understanding about the composition of massive sulphide ores in Ontario (excluding Sudbury deposits). Some previously unrecognized elements might occur in sufficient quantities to contribute to the economic viability of a prospect. This study might also provide characteristic chemical compositions of massive sulphide deposits that can be utilized to vector in on unrecognized or deeply buried mineral deposits.

ANALYTICAL PROCEDURE

A total of 57 massive sulphide samples collected from Ontario copper-zinc deposits and prospects were examined and the percentage of each sulphide mineral present estimated visually (most samples contained 50% or more sulphide minerals). The samples were then shipped to GeoLabs for analysis. They were analyzed using GeoLabs packages IRC-100 (CO2, S); GFA-PBG (Ag, Au); IML-100 (Ag, As, Au, Bi, Cd, Co, Cu, Hg, Ir, Mo, Ni, Pb, Pd, Pt, Rh, Sb, Se, Sn, Te, Tl, Zn); and IAT-100 (Al, Ba, Ca, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Na, Ni, Pb, Sc, Sr, Ti, V, Y, Zn). All the samples were pulverized using a chrome steel mill and put into solution using multi-acid open vessel digestion (method SOL-OT3) for package IAT-100 and Aqua Regia digestion (method SOL-ARD) for analytical package IML-100. Samples with base metal assays exceeding upper detection limits for package IML-100 or IAT-100 were reanalyzed using analytical package AAF-104 (Co, Cu, Ni, Pb and Zn) to establish the concentration of these elements. Some other elements with assays exceeding their upper detection limit were diluted and re-assayed. Data from such assays are "reported for information purposes only" and are indicated with bolded text in the tables below.

RESULTS AND DISCUSSION

The locations of 57 VMS samples collected and submitted to GeoLabs for analysis are shown on Figure 1. These include the 27 samples reported and discussed in this recommendation for exploration for which assay results have been obtained and are listed in Tables 2a and 2b.

Results for 27 VMS samples have high Cu, Zn and Pb assays (Table 2a) consistent with the chalcopyrite, sphalerite and galena seen in the hand samples. Silver is an important component of VMS-type mineralization, as indicated by the 25 samples analyzed, containing an average of more than 36 g/t silver. The silver content of Kidd Creek Mine bornite and galena samples were excluded from the average because they contain more than 1800 g/t (>50 oz/t) Ag, which is 50 times greater than the average of the other 25 VMS samples. Gold assays greater than 0.5 g/t were measured in 10 of 27 samples analyzed and obtained from 7 of 12 deposits.

An average of 1741 ppm of Co (Table 2b) was measured in 7 of 27 VMS samples. This concentration indicates that the samples contain more than 3.8 pounds of cobalt per tonne. These cobalt concentrations do not appear to be caused by pulverizing the samples using the chrome steel mortar because enrichment tests done with silica sand indicate that the mortar adds less than 5 ppm of Co. The 1741 ppm of Co in the samples indicates that they could contribute just under US$115 per tonne (at US$29.65/lb., *see* Table 1) to the value of mineralization extracted from the deposits. The more than 1000 ppm of Co detected in 2 of 4 Kidd Creek samples analyzed are consistent with unpublished mine data (Gemmell 2013). Most of the higher cobalt assays occur in samples that also have high copper contents.

Many VMS samples also contain measureable amounts of Cd, Se, Sn, Ti, Tl and V. The Cd and Se concentrations exceed 200 and 150 ppm, respectively, in 10 of the 27 samples analyzed. Grinding enrichment contributed less than 5 ppm to the amount of Cd, less than 168 ppm of Ti and an unknown amount of Se to the samples. The Potter deposit differs from other VMS deposits in that it has Cr, Ni and Ti values that are more than 5 times higher than those in the 26 other VMS samples for which assays results have been obtained. Two Genex and 1 Turnbull sample also have high Ti assays. Two Kidd Creek samples were the only ones with measureable concentrations of Pd and Rh worth about US$5 per tonne.

Geochemistry of Volcanogenic Massive Sulphide Deposits

CONCLUSION AND RECOMMENDATIONS

Analysis of 27 VMS samples contained high concentrations of Ag, Au and Co that might impact the economic viability of deposits being explored. Cobalt concentrations, averaging 1741 ppm (1.7 kg/t or 3.8 lbs/t) and measured in 7 of 27 VMS samples, are currently worth just under US$115/t. Given the value of the accessory elements, the geochemistry of massive sulphide deposits and prospects should be fully characterized to ensure economic assessments are complete.

Bornite and galena samples from the Kidd Creek Mine both contained more than 50 ounces of silver per tonne, an amount that greatly exceeds the average silver content in VMS samples of just over 1 ounce per tonne (25 samples). These anomalous silver concentrations suggest that the presence of bornite and galena in VMS deposits warrant special attention.

ADDITIONAL COMMENTS

Metallurgical testing is required to establish if elements such as cobalt (Table 2b) are economically recoverable or if their distribution in minerals is such that they are considered contaminants and will result in a monetary penalty by the smelter.

A total of about 100 massive sulphide samples have been submitted to GeoLabs for analysis. Results received for these samples, including the original batch reported in Recommendations for Exploration 8 and 9, and those currently undergoing analysis, will be reported in the 2017 Report of Activities for the Timmins District or a separate Open File Report (along with the results of blank, duplicate and standards analyzed with the samples).

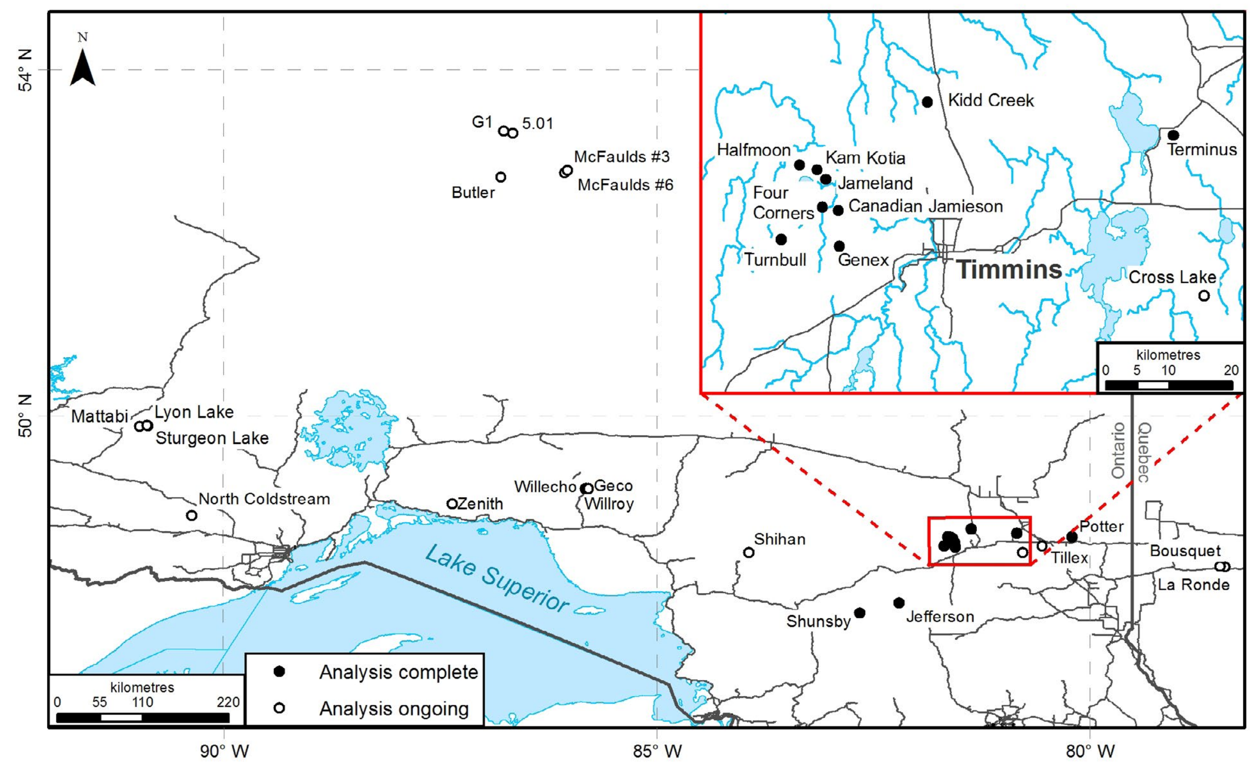

Figure 1. Map of northern Ontario and part of the Timmins District (inset) showing the locations of all 57 VMS samples submitted for analysis and the 27 samples already analyzed (solid circles) and discussed in this report.

Table 2a. VMS sample assays. Assays exceeding their upper detection limit are indicated with bolded text.

Deposit	Description	Cu ppm	Ni ppm	Pb ppm	Zn ppm	S wt%	Ag ppm	Au oz/t	Au ppm	As ppm	Ba ppm	Bi ppm	Cd ppm
	Detection Limit	1	2	2	3	0.0	0.2	0.016	0.002	0.1	1	0.02	0.02
Kidd Creek	Brn	**412327**	174	80	429	24.5	**2648**	0.019	0.74	>1800	2.0	162.7	26.2
Kidd Creek	Cpy	191107	14	310	28601	33.7	**303**	<0.016	0.03	1249	7.0	9.3	**135.7**
Kidd Creek	Sph	10994	9	724	353547	20.2	24.62	<0.016	0.02	>1800	1.0	8.6	**1452.6**
Kidd Creek	Gln	1196	14	64388	137473	22.5	**1845**	<0.016	0.07	73	1.0	3.6	**353.2**
Kam Kotia	Sph	16505	4	369	83131	40.4	20.60	0.018	0.78	>1800	3.0	66.5	**210.3**
Kam Kotia	Cpy	80444	15	1712	13715	33.2	52.27	0.024	0.91	1404	4.0	142.0	30.8
Terminus	Dun20-25; 447 m	21191	80	1306	120637	29.6	36.51	0.056	1.02	284	4.0	1.2	**292.8**
Terminus	Dun20-25; 446 m	28136	83	1466	96902	31.6	49.47	0.048	0.95	209	3.0	1.8	**203.5**
Cayenne Chili	Jefferson	2937	79	34361	245371	30.3	17.01	<0.016	0.06	29	2.0	0.4	**938.5**
Potter	Sph	5755	488	118	974	20.7	1.69	<0.016	0.02	2	11.5	0.6	2.4
Genex	Sph	1621	10	1613	27376	5.5	4.05	0.026	0.87	135	330.0	11.4	**74.8**
Genex	Cpy	47710	29	140	1749	6.7	6.84	<0.016	0.38	61	6.0	37.3	5.5
Genex	Cpy	80253	51	2493	12287	28.9	**119**	0.09	3.79	**38930**	175.0	406.0	36.2
Turnbull	Sph	2418	12	26	334107	13.1	7.68	0.018	0.24	101	29.0	4.4	**894.4**
Halfmoon	Py+Sph (Honey)	1920	9	240	28783	39.5	22.53	<0.016	0.58	741	5.0	26.5	**67.9**
Halfmoon	Sph	39853	18	515	92931	27.6	55.08	<0.016	0.67	214	4.0	36.6	**260.2**
Jameland	90% Pyrite	5337	3	302	8844	42.2	14.38	<0.016	0.19	**2148**	14.0	30.0	10.9
Jameland	Py-Cpy-Sph 60-20-20	28404	14	722	58691	38.0	53.94	0.022	0.28	1140	5.0	48.9	**145**
Can Jameson	Py-Cpy-Sph 40-20-40	11263	15	1257	263225	23.6	14.56	<0.016	0.30	285	4.0	35.4	**664**
Can Jameson	Py-Cpy-Sph 40-20-40	35870	21	548	25708	28.6	27.09	<0.016	0.55	1432	15.0	84.5	**68**
4 Corners	Py-Sph 40-60	113	9	34	**480627**	20.9	24.99	<0.016	3.90	153	<1.0	0.6	**4188**
Shunsby Pros	Py-Sph 20-20	792	131	520	9488	28.4	2.48	<0.016	0.01	247	30.0	2.9	24.2
Shunsby Pros	80% Gln	107	2	**218693**	6406	12.0	59.20	<0.016	0.01	3	<1.0	1.4	33.8
Shunsby Pros	20% Py	366	79	886	16062	20.1	2.76	<0.016	0.00	44	61.0	2.5	34.9
Cayenne - N	Cpy-Py 50-20	69	74	106	427	20.5	0.88	<0.016	0.03	10	10.0	0.3	1.5
Cayenne - N	Cpy-Py 30-40	72	84	69	478	22.3	0.91	<0.016	0.03	8	8.0	0.3	2.2
Mortimer Zn	BIF - 30% Py	25	185	18	74	10.6	0.41	<0.016	0.01	99	21.0	0.0	0.2

Abbreviations: BIF – banded iron formation, Brn – bornite, Cpy – chalcopyrite, Gln – galena, Py – pyrite, Sph – sphalerite.

Table 2b. VMS sample assays. Assays exceeding their upper detection limit are indicated with bolded text.

Deposit	Description	Co ppm	Cr ppm	Mo ppm	Pd ppm	Pt ppm	Sb ppm	Sc ppm	Se ppm	Sn ppm	Te ppm	Ti ppm	Tl ppm	V ppm
	Detection Limit	1	2	0.06	0.02	0.005	0.01	1.0	0.2	0.1	0.02	1	0.001	1
Kidd Creek	Brn	2064	86	2.9	0.08	<0.005	21.8	12.0	**6643.3**	**711.5**	1.7	15	0.31	6.0
Kidd Creek	Cpy	1135	57	1.9	0.04	<0.005	12.3	3.0	**570.9**	**103.3**	1.8	7	1.35	6.0
Kidd Creek	Sph	276	84	1.0	<0.02	<0.005	22.9	<1	**164.0**	5.8	0.2	<1	0.07	2.0
Kidd Creek	Gln	16	91	1.3	<0.02	<0.005	**1812.8**	<1	11.7	19.9	0.8	10	3.23	4.0
Kam Kotia	Sph	26	105	1.7	<0.02	<0.005	30.2	<1	81.7	3.8	0.4	1	0.69	7.0
Kam Kotia	Cpy	1689	105	1.9	0.02	<0.005	46.7	1.0	**301.6**	7.4	3.5	4	1.39	7.0
Terminus	Dun20-25; 447 m	1975	50	0.5	<0.02	<0.005	5.6	<1	5.8	74.7	0.3	62	0.38	12.0
Terminus	Dun20-25; 446 m	1842	47	0.4	<0.02	<0.005	5.6	<1	4.7	>90	0.2	62	0.55	12.0
Jefferson		191	75	5.1	<0.02	<0.005	1.0	4.0	1.2	0.7	0.2	187	0.22	30.0
Potter	Sph	229	>500	2.7	<0.02	0.005	0.1	29.0	21.7	0.8	0.2	5781	0.04	225.0
Genex	Sph	58	153	8.5	<0.02	<0.005	2.4	9.0	35.1	2.5	0.1	1661	0.56	47.0
Genex	Cpy	186	29	2.3	0.02	<0.005	0.2	22.0	**151.0**	9.8	0.1	9181	0.03	102.0
Genex	Cpy	1718	73	25.6	0.02	<0.005	37.8	5.0	**309.6**	43.3	12.6	364	0.75	31.0
Turnbull	Sph	394	78.5	1.9	<0.02	<0.005	0.1	8.0	9	6.6	0.1	2013	0.05	53.0
Halfmoon	Py+Sph (Honey)	43	62	1.7	<0.02	<0.005	6.1	2.0	42.4	2.9	0.8	266	>11	18.0
Halfmoon	Sph	102	93	2.3	<0.02	<0.005	1.2	1.0	**187.5**	19.6	0.7	242	2.26	10.0
Jameland	90% Pyrite	186	98	2.2	<0.02	<0.005	29.3	<1	**91.0**	1.9	0.3	178	2.95	16
Jameland	Py-Cpy-Sph 60-20-20	474	79	2.8	<0.02	<0.005	33.7	<1	**236.0**	6.0	0.1	9	3.37	11
Can Jameson	Py-Cpy-Sph 40-20-40	464	71	8.1	<0.02	<0.005	22.6	<1	**237.0**	6.2	4.8	6	2.86	6
Can Jameson	Py-Cpy-Sph 40-20-40	1766	120	16.9	<0.02	<0.005	70.6	4.0	**154.0**	10.3	4.0	55	4.59	27
4 Corners	Py-Sph 40-60	237	<2	1.8	0.02	<0.005	6.0	<1	9.5	0.2	0.1	<1	0.01	<1
Shunsby Pros	Py-Sph 20-20	860	104	8.1	<0.02	<0.005	15.3	6.0	30.3	4.7	6.9	360	0.32	41
Shunsby Pros	80% Gln	4	8	0.5	<0.02	<0.005	37.7	<1	16.8	1.8	0.8	24	0.18	2
Shunsby Pros	20% Py	198	108	21.8	<0.02	<0.005	13.2	13.0	24.5	9.2	4.7	662	0.46	73
Cayenne - N	Cpy-Py 50-20	41	46	36.3	<0.02	<0.005	0.2	<1	1.5	0.4	0.5	175	0.05	26
Cayenne - N	Cpy-Py 30-40	50	36	5.8	<0.02	<0.005	0.1	<1	0.9	0.3	0.4	100	0.04	25
Mortimer Zn	BIF - 30% Py	53	93	3.9	<0.02	<0.005	2.6	<1	1.4	0.2	0.1	18	1.83	18

Abbreviations: BIF – banded iron formation, Brn – bornite, Cpy – chalcopyrite, Gln – galena, Py – pyrite, Sph – sphalerite.

Geochemistry of Volcanogenic Massive Sulphide Deposits

REFERENCES

Franklin, J.M. and Thorpe, R.J. 1982. Comparative metallogeny of the Superior, Slave and Churchill provinces; *in* H.S. Robinson Memorial Volume, Precambrian Sulphide Deposits, Geological Association of Canada, Special Paper 25, p.3-90.

Gemmell, T.P. 2013. Geology of the Kidd Creek deep orebodies – Mine D, Western Abitibi Subprovince, Canada; unpublished MSc thesis, University of Ottawa, Ottawa, 162p.

HIGHLIGHTS

- **Accessory metals in magmatic, sedex and other massive sulphide deposits might have economically important concentrations.**
- **Magmatic (copper-nickel) deposits contain cobalt that could add more than US$65/tonne to the value of ore.**
- **Early micrometallurgical testing is recommended to establish if accessory metals are recoverable.**

Geochemistry of Copper-Nickel, Sedex and Other Massive Sulphide Deposits

SUMMARY

Analysis of 6 copper-nickel, 3 lead-zinc (sedex) and 8 "other" massive sulphide samples (17 in total) produced high Cu, Ni, Pb and Zn assays as well as high concentrations of accessory Ag, Au, Co, Pd, Pt and Rh. The results indicate that the concentration of accessory elements in some deposits or prospects being explored might impact their economic viability. Given this possibility, the geochemistry of massive sulphide deposits should be fully characterized to ensure economic assessments are complete.

Cobalt concentrations greater than 1000 ppm (>1.0 kg/t or >2.2 lbs/t) were obtained for 4 of 6 copper-nickel massive sulphide samples analyzed and is currently worth more than US$65/t. The Redstone Mine sample contained 1434 ppm Co and is worth about US$93/t.

Pd, Pt and Rh values in the 6 copper-nickel samples averaged 2.42, 0.228 and 0.036 g/t, respectively, and have a current total value of about US$80 per tonne.

Possible sedex-type ore from the Hurdman deposit (3 samples) contain an average of 0.83 g/t of Au and 127.8 g/t Ag worth a total of US$103 per tonne (US$34.07 plus US$69.00), in addition to high Pb and Zn assay values.

INTRODUCTION

Published geochemical data for copper-nickel and sedimentary-exhalative (sedex) massive sulphide deposits typically includes Cu, Ni, Au and platinum group elements (Rh, Pd, Pt, Ir, Os and Ru); and Pb, Zn, Ag, Cd, Sn and W assay results, respectively (Hamilton et al. 1982; Robinson and Hutchinson 1982; and Lyndon 2007). Production data also indicate that cobalt is recovered from some copper-nickel deposits (Lyndon 2007). Unpublished data indicate that some deposits or prospects contain other elements that might be of economic importance. For example, a copper-nickel sulphide float in Keefer Township was reported to assay 1.26% Ni, 1.48% Cu and 0.49% Co (MacKenzie 1965). The 10.8 pounds per tonne of Co in this float is currently worth US$320 per tonne (*see* Table 1).

Table 1. Value of metals (October 5, 2017).

Element	US$/g	Element	US$/lb	Element	US$/lb
Ag	0.54	**Bi**	4.68	**Pb**	1.17
Au	41.05	**Cd**	0.88	**Sb**	3.71
Ir	21.70	**Co**	29.65	**Se**	26.00
Pd	29.61	**Cr**	3.40	**Sn**	9.45
Pt	29.29	**Cu**	3.83	**Te**	14.55
Rh	35.85	**Mo**	7.26	**78%Ti**	16.82
		Ni	4.83	**V_2O_5**	22.10

Source of Metal Prices
Ag, Au, Pd, Pt, Rh – Kitco.com; Cu, Mo, Ni, Pb, Zn – London Metals Exchange
Cd, Ir, Se, V_2O_5 – Northern Miner; Bi, Co, Cr, Sb, Sn, Te, 78%Ti – Metalbulletin.com

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Geochemistry of Copper-Nickel, Sedex and Other Massive Sulphide Deposits

Elements analyzed on about 100 massive sulphide samples collected and submitted to Geoscience Laboratories (GeoLabs) in Sudbury (including the 17 Copper-Nickel, Sedex and Other samples in this Recommendation for Exploration and the 27 VMS samples in Recommendation 8: "Geochemistry of Volcanogenic Massive Sulphide Deposits") will provide a broad understanding about the composition of massive sulphide ores in Ontario (excluding Sudbury deposits). It is hoped this study encourages the analysis of more elements and the discovery of new components that contribute to the economic viability of massive sulphide deposits and prospects. The chemical characterization of massive sulphide deposit compositions might also be utilized to vector in on unrecognized or deeply buried mineral deposits.

ANALYTICAL PROCEDURE

A total of 41 massive sulphide samples collected from Ontario copper-nickel, possible sedex- and vein-hosted deposits and prospects were examined and the percentage of each sulphide mineral estimated visually (most samples contained 50% or more sulphide minerals). The samples were then shipped to GeoLabs in Sudbury for analysis. The samples were grouped into "Copper-Nickel" (Cu-Ni), "Sedex" (Zn-Pb) and "Other" types. They were analyzed using GeoLabs packages IRC-100 (CO_2, S); GFA-PBG (Ag. Au); IML-100 (Ag, As, Au, Bi, Cd, Co, Cu, Hg, Ir, Mo, Ni, Pb, Pd, Pt, Rh, Sb, Se, Sn, Te, Tl, Zn); and IAT-100 (Al, Ba, Ca, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Na, Ni, Pb, Sc, Sr, Ti, V, Y, Zn). All the samples were pulverized using a chrome steel mill and put into solution using multi-acid open vessel digestion (method SOL-OT3) for package IAT-100 and Aqua Regia digestion (method SOL-ARD) for analytical package IML-100. The copper-nickel samples are also being analyzed using package IMP-200 to measure Au, Pt, Pd, Rh, Ru and Ir concentrations. Samples with base metal assays exceeding the upper detection limit for packages IML-100 or IAT-100 were reanalyzed using analytical package AAF-104 (Co, Cu, Ni, Pb, Zn) in order to establish the concentration of these elements. Some other elements with assays exceeding their upper detection limit were diluted and re-assayed. Data from such assays are "reported for information purposes only" and are indicated with bolded text in the tables below.

RESULTS AND DISCUSSION

The locations of 41 copper-nickel, sedex- and vein-hosted massive sulphide samples collected and submitted to GeoLabs for analysis are shown on Figure 1. These include the 17 samples reported and discussed in this recommendation for exploration for which assay results have been obtained and are listed in Tables 2a, 2b, 3a, 3b, 4a and 4b.

Results for the 17 samples have high Cu, Ni, Pb and Zn assays (*see* Tables 2a, 3a and 4a) which are consistent with the chalcopyrite, pentlandite, pyrrhotite, sphalerite and galena seen in the hand samples.

The Co content of all 6 Cu-Ni samples (*see* Table 2b), including 4 samples from copper-nickel mines (Alexo, Langmuir, Montcalm and Redstone), have average concentrations of 1125 ppm and 1379 ppm (1.38 kg/t), respectively. The 1.38 kg/t, or 3.0 lbs/t, of Co is worth US$90.11 per tonne at the time of writing (*see* Table 1). These Co concentrations do not appear to be caused by using a chrome steel mortar to pulverize the samples because enrichment tests done using silica sand indicate that the mortar adds less than 5 ppm of Co.

Five of the 6 Cu-Ni samples contain more than 1.5 g/t of Ag for an average of 2.1 g/t. All 3 sedex samples contain >10 g/t Ag and one contains 360 g/t (10 oz/t) of Ag (*see* Table 3b) for an average grade of 127.8 g/t. The "Other" group sulphide samples contain up to 74 g/t Ag (*see* Table 4b).

Gold values in the Cu-Ni samples are generally low (average 0.34 g/t) although 1.38 g/t of Au is reported for the Redstone sample along with 5.24 g/t of Ag (*see* Table 2a).

Geochemistry of Copper-Nickel, Sedex and Other Massive Sulphide Deposits

Pd, Pt and Rh values in the Cu-Ni samples average 2.42, 0.228 and 0.036 g/t, respectively (*see* Table 2b), and are worth a total of almost US$80 per tonne. Ag, Co and PGEs (Rh, Pd, Pt) are the only elements in the Cu-Ni samples that have consistently high values (*see* Tables 2a and 2b).

Analysis for the 3 sedex-type samples from the Hurdman deposit have high Zn and Pb values (Table 3a) that are consistent with the sphalerite and galena seen in the hand samples. The sedex samples also contain an average (3 samples) of 0.83 g/t of Au and 127.8 g/t Ag worth a total of US$103 per tonne (US$34.07 plus US$69.00, respectively).

The "other" sulphide samples analyzed do not have consistently high concentrations of any particular element, but there are some high concentrations of Ag, Au, Bi, Mo and Pd in individual samples (*see* Tables 4a and 4b). The 2 Leckie and 2 Tribag mine samples average 20.4 and 54.7 g/t of Ag, respectively. The Tribag results are consistent with high silver assays found in Keweenaw copper deposits on the south shore of Lake Superior. Deposits with high Au values include the Leckie mine (2 samples averaged 5.31 g/t Au) and the Ryan Lake Mine sample (it contained 17.62 g/t Au). A vein sample collected from Bartlett Township did not contain gold or base metals but did contain 8.45 ppm of Ag, 742 ppm of Mo, 1144 ppm of Bi and 603 ppm of Te. The Ag, Bi, Mo and Te assay values suggest that additional exploration might be warranted where the sample was collected. The 1.02 g/t of Pd in the Kanichee Mine sample is worth US$30.02 per tonne.

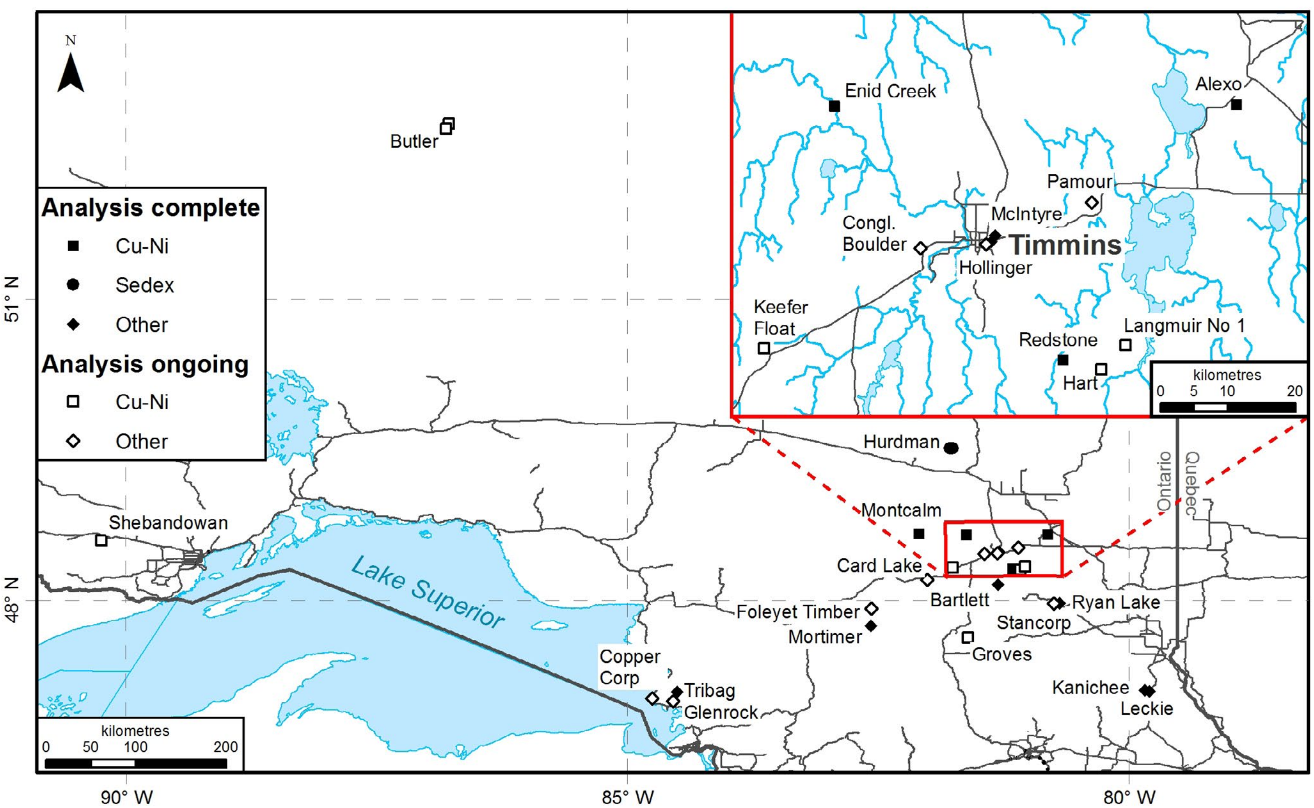

Figure 1. Map of northern Ontario and part of the Timmins District (inset) showing the locations of all 41 Cu-Ni, Sedex and Other massive sulphide samples submitted for analysis and the 17 samples already analyzed (these have filled symbols) and discussed in this report.

Geochemistry of Copper-Nickel, Sedex and Other Massive Sulphide Deposits

Table 2a. Cu-Ni sample assays.

Deposit / Location	Description	Cu ppm	Ni ppm	Pb ppm	Zn ppm	S wt%	Ag ppm	Au oz/t	Au ppm	As ppm	Ba ppm	Bi ppm	Cd ppm
	Detection Limit	1	2	2	3	0.003	0.2	0.016	0.002	0.1	1	0.02	0.02
Enid Creek	Pyrr + Cpy	6955	10590	2	111	16.99	1.42	<0.016	0.026	2	54	0.32	0.6
Enid Creek	Pyrr + Cpy	9632	11866	2	127	8.69	1.46	<0.016	0.166	330	49	0.26	0.7
Langmuir No. 1	Pyrr + Pent	1459	57436	5	22	35.59	0.68	<0.016	0.007	1	6	0.18	0.0
Montcalm	Pyrr + Pent + Cpy	5087	32279	1	60	30.47	2.24	<0.016	0.01	2	17	0.44	0.3
Redstone Mine	Pyrr + Pent	1152	388560	57	80	25.02	5.24	0.02	1.383	1010	8	47.99	0.1
Alexo Mine	Pent	1262	45533	8	316	23.92	1.67	<0.016	0.433	9	7	0.83	1.1

Abbreviations : Cpy – chalcopyrite, Pent – pentlandite, Pyrr – pyrrhotite.

Table 2b. Cu-Ni sample assays.

Deposit / Location	Description	Co ppm	Cr ppm	Mo ppm	Pd ppm	Pt ppm	Rh ppm	Sb ppm	Sc ppm	Se ppm	Sn ppm	Te ppm	Ti ppm	Tl ppm	V ppm
	Detection Limit	1	2	0.1	0	0.005	0.003	0.01	1	0.2	0.1	0	1	0.001	1
Enid Creek	Pyrr + Cpy	661	134	0.9	1.7	0.08	0.017	0.05	9	20.2	0.2	4	2760	0.12	111
Enid Creek	Pyrr + Cpy	572	130	0.9	3.2	0.16	0.065	0.26	20	22.4	0.2	2.5	2513	0.20	155
Langmuir No 1	Pyrr + Pent	1298	201	1.0	0.2	0.11	0.053	0.02	<1	3.8	0.1	0.8	31	0.21	23
Montcalm	Pyrr + Pent + Cpy	1430	289	0.5	0.0	0.01	0.006	0.02	4	43.1	<0.1	2.8	264	0.07	32
Redstone Mine	Pyrr + Pent	1434	73	37.2	>5	0.01	0.022	8.07	<1	38.5	0.1	>40	293	1.11	14
Alexo Mine	Pent	1355	>500	0.5	4.4	1.01	0.051	0.06	4	16.2	1.6	5.7	351	0.94	83

Abbreviations : Cpy – chalcopyrite, Pent – pentlandite, Pyrr – pyrrhotite.

CONCLUSION AND RECOMMENDATIONS

Chemical analysis of massive sulphide samples found high Cu, Ni, Pb and Zn assays consistent with the chalcopyrite, pentlandite, sphalerite and galena they contain, as well as anomalous Ag, Au, Co, Pd, Pt and Rh. The anomalous elements could contribute up to US$300 per tonne to the development of some massive sulphide exploration prospects as well as being a source for strategic metals such as tellurium. Given the value of the accessory elements, the geochemistry of massive sulphide deposits and prospects should be fully characterized to ensure economic assessments are complete.

Anomalous elements reported in Tables 2a, 2b, 3a, 3b, 4a and 4b require metallurgical testing to establish if they are recoverable. It is recommended that micrometallurgical testing (using small core samples) be done early when exploring a massive sulphide deposit or prospect to ensure the exploration program is conducted optimally.

ADDITIONAL COMMENTS

A total of about 100 massive sulphide samples have been submitted to GeoLabs for analysis. Results received for these samples, including the original batch reported in Recommendations for Exploration 8 and 9, and those currently undergoing analysis, will be reported in the 2017 Report of Activities for the Timmins District or in a separate Open File Report (along with the results of blank, duplicate and standards analyzed with the samples).

Table 3a. Sedex sample assays. Assays exceeding their upper detection limit are indicated with bolded text.

Deposit	Description	Cu ppm	Ni ppm	Pb ppm	Zn ppm	S wt%	Ag ppm	Au oz/t	Au ppm	As ppm	Ba ppm	Bi ppm	Cd ppm
	Detection Limit	1	2	2	3	0.003	0.2	0.016	0.002	0.1	1	0.02	0.02
Hurdman Tp.	70% Pyrr + Py + Sph	891	30	338	64503	29.72	**362**	0.04	1.19	2	160	2.6	**198**
Hurdman Tp.	Pyrr + Py + Sph	346	31	133	25317	27.53	10.05	0.04	1.07	2.4	236	0.8	**68**
Hurdman Tp.	Semi-massive sulphides	667	61	130	7649	38.75	11.28	<0.016	0.24	1.9	23	2.6	16.13

Abbreviations : Py – pyrite, Pyrr – pyrrhotite, Sph - sphalerite.

Table 3b. Sedex sample assays.

Deposit	Description	Co ppm	Cr ppm	Mo ppm	Pd ppm	Pt ppm	Rh ppm	Sb ppm	Sc ppm	Se ppm	Sn ppm	Te ppm	Ti ppm	Tl ppm	V ppm
	Detection Limit	1	2	0.1	0.02	0.005	0.003	0.01	1	0.2	0.1	0	1	0.001	1
Hurdman Tp.	70% Pyrr + Py + Sph	128	86	8.2	<0.02	<0.005	<0.003	0.1	<1	18.6	0.6	0.1	275	0.1	14
Hurdman Tp.	Pyrr + Py + Sph	63	95	7.2	<0.02	<0.005	<0.003	0.1	2	22.5	0.7	0.1	430	0.2	23
Hurdman Tp.	Semi-massive sulphides	75	58	2.1	<0.02	<0.005	<0.003	0.2	1	7.6	0.3	0.2	256	0.9	19

Abbreviations : Py – pyrite, Pyrr – pyrrhotite, Sph - sphalerite.

Table 4a. "Other" sample assays. Assays exceeding their upper detection limit are indicated with bolded text.

Deposit	Description	Cu ppm	Ni ppm	Pb ppm	Zn ppm	S wt%	Ag ppm	Au oz/t	Au ppm	As ppm	Ba ppm	Bi ppm	Cd ppm
	Detection Limit	1	2	2	3	0.003	0.2	0.016	0.002	0.1	1	0.02	0.02
Bartlett Tp.	Py and Qtz	22.5	99	32	21	41.3	**8.5**	<0.016	0.07	10	4	**1144.2**	0.1
Leckie Mine	Cpy	3734	45	209	243	16.6	16	0.14	5.31		178	221	1.0
Leckie Mine	Cpy	4657	69	274	82	24.4	25	0.168	5.31		31	376	0.4
Kanichee	Cpy	12745	1073	63	186	1.4	2.3	<0.016	0.15	669	765	10	1.1
Ryan Lake	Moly	58	12	16	144	3.5	1.9	0.828	17.62	340	813	2	0.2
McIntyre - Cu	Cpy	>15000	33	15	51	4.2	1.4	<0.016	0.06	74	144	0	0.2
Tribag	West Bx	>12000	128	94	1774	5.7	36	0.02	0.07	242		138	7.7
Tribag	Breton	>12000	138	139	3001	11.1	74	<0.016	0.21	446		69	14.6

Abbreviations: Bx - breccia, Cpy – chalcopyrite, Moly – molybdenite, Py – pyrite, Qtz – quartz.

Table 4b. "Other" sample assays. Assays exceeding their upper detection limit are indicated with bolded text.

Deposit	Description	Co ppm	Cr ppm	Mo ppm	Pd ppm	Pt ppm	Rh ppm	Sb ppm	Sc ppm	Se ppm	Sn ppm	Te ppm	Ti ppm	Tl ppm	V ppm
	Detection Limit	1	2	0.06	0.02	0.005	0.003	0.01	1	0.2	0.1	0	1	0	1
Bartlett Tp.	Py and Qtz	177	262	742	<0.02	<0.005	0.003	0.1	<1	6.4	0.1	**603.4**	7	0.02	7
Leckie Mine	Cpy	71	101	1.1	<0.02	<0.005	<0.003	48.6	6	1.8	0.6	0.5	843	0.16	39
Leckie Mine	Cpy	190	97	1.6	<0.02	<0.005	<0.003	36.6	2	3.3	0.6	1.0	564	0.30	26
Kanichee	Cpy	6	137	2.2	1.02	0.007	0.005	0.3	5	2.3	8.9	3.6	1408	0.24	43
Ryan Lake	Moly	3	299	**4212.0**	<0.02	<0.005	0.004	64.3	1	2.4	0.3	0.4	400	3.56	244
McIntyre - Cu	Cpy	24	334	15.1	<0.02	<0.005	<0.003	9.3	1	6.55	3	0.1	24	0.02	3
Tribag	West Bx	69	278	11.0	0.02	<0.005	0.006	7.7	10	4.8	0.9	2.8	1195	0.17	58
Tribag	Breton	203	242	46.9	0.03	<0.005	0.006	10.8	10	11.3	0.8	3.4	1077	0.19	59

Abbreviations: Bx - breccia, Cpy – chalcopyrite, Moly – molybdenite, Py – pyrite, Qtz – quartz.

Geochemistry of Copper-Nickel, Sedex and Other Massive Sulphide Deposits

REFERENCES

Hamilton, J.M., Bishop, D.T., Morris, H.C. and Owens, O.E. 1982. Geology of the Sullivan orebody, Kimberley, B.C., Canada; *in* H.S. Robinson Memorial Volume, Precambrian Sulphide Deposits, Geological Association of Canada, Special Paper 25, p.598-665.

Lyndon, J.W. 2007 An overview of the economic and geological contexts of Canada's major mineral deposit types; *in* Mineral Deposits of Canada: A Synthesis of Major Deposit-types, District Metallogeny, the Evolution of Geological Provinces and Exploration Methods, Geological Association of Canada, Mineral Deposits Division, Publication No. 5, p.3-48.

MacKenzie, C.D. 1965. T-1148 Geological Survey, Keefer Township – Group #2, Hollinger Gold Mines, Ltd.; Timmins Resident Geologist Office, Keefer Township, assessment file 42A05SE0218, 3p. and a geological map.

Robinson, D.J. and Hutchinson, R.W. 1982. Evidence for a volcanogenic-exhalative origin of a massive nickel sulphide deposit at the Redstone, Timmins, Ontario; *in* H.S. Robinson Memorial Volume, Precambrian Sulphide Deposits, Geological Association of Canada Special Paper 25, p.211-254.

HIGHLIGHTS

- **101 nickel-copper and 37 copper-zinc occurrences are open for staking in the Timmins District.**
- **These occurrences might also contain other commodities such as cobalt.**

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Massive Sulphide Deposits and Prospects Open for Staking

SUMMARY

Analysis of the Mineral Deposit Inventory (MDI) for the Timmins District has identified 138 unstaked massive sulphide mineral occurrences and prospects in the Timmins District. They are prospective targets for exploration, especially for commodities including cobalt, because the mining rights to these deposits and occurrences are open for staking. The number of occurrences identified in this analysis highlight that there is significant unstaked mineral potential in the Timmins District.

METHODOLOGY

Unstaked nickel-copper and copper-zinc occurrences were identified first by selecting all mineral occurrences in the MDI database (Ontario Geological Survey 2017) in 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 94 unstaked nickel-copper occurrences and 7 prospects, and 37 copper-zinc occurrences (numbers valid as of November 1, 2017). Some of these occurrences might contain cobalt concentrations in the 1000 to 2000 ppm range (*see* "Geochemistry of Volcanogenic Massive Sulphide Deposits" and "Geochemistry of Copper-Nickel, Sedex and Other Massive Sulphide Deposits" recommendations, articles 8 and 9, respectively). Two maps showing the locations of unstaked occurrences were created: one for copper-zinc (VMS) (Figure 1) and the other for nickel-copper occurrences (Figure 2). Discretionary occurrences were omitted, although they also represent prospective targets. Fripp and Price townships have the most copper-zinc occurrences open for staking, with 4 each. Mann and MacDiarmid townships have the most open nickel-copper occurrences, with 11 and 7, respectively. Detailed maps are available at the Timmins Resident Geologist Office.

CAUTIONARY STATEMENT

The occurrences presented on these maps were open for staking at the time of writing (November 1, 2017). However, conversion to online map staking during the winter of 2018 will cause some claim boundaries to migrate and might cause a few occurrences to be captured by existing claims that have been enlarged by migration of the boundaries. Some occurrences also fall in areas where patented or leased claims exist that only cover the surface rights. In those situations, it might not be immediately apparent that mineral rights are open for staking when

Massive Sulphide Deposits and Prospects Open for Staking

viewing in CLAIMaps. 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 readers of this recommendation for exploration consult original documents to verify the location of any occurrence before staking claims.

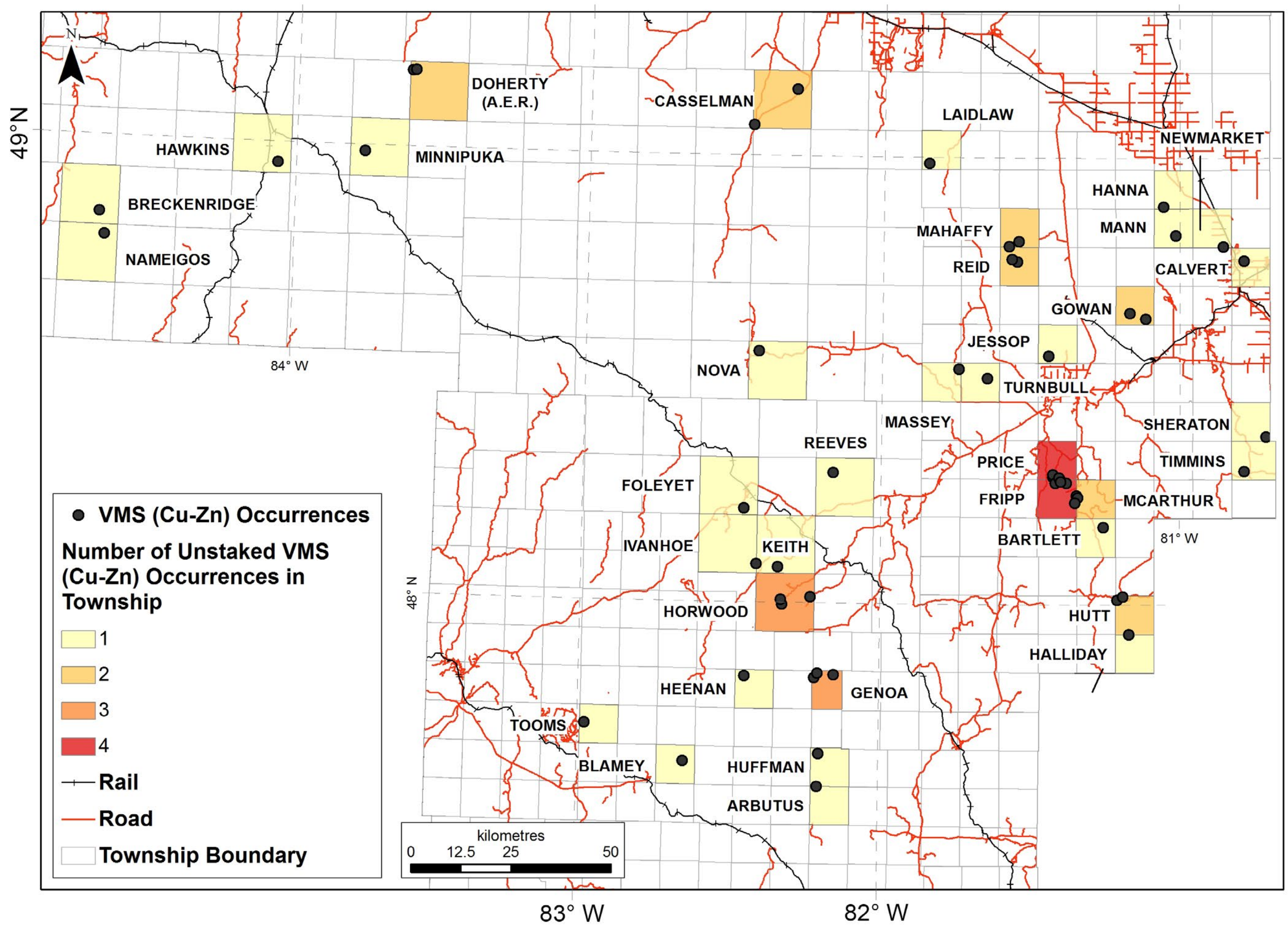

Figure 1. Unstaked copper-zinc occurrences in the Timmins District.

Massive Sulphide Deposits and Prospects Open for Staking

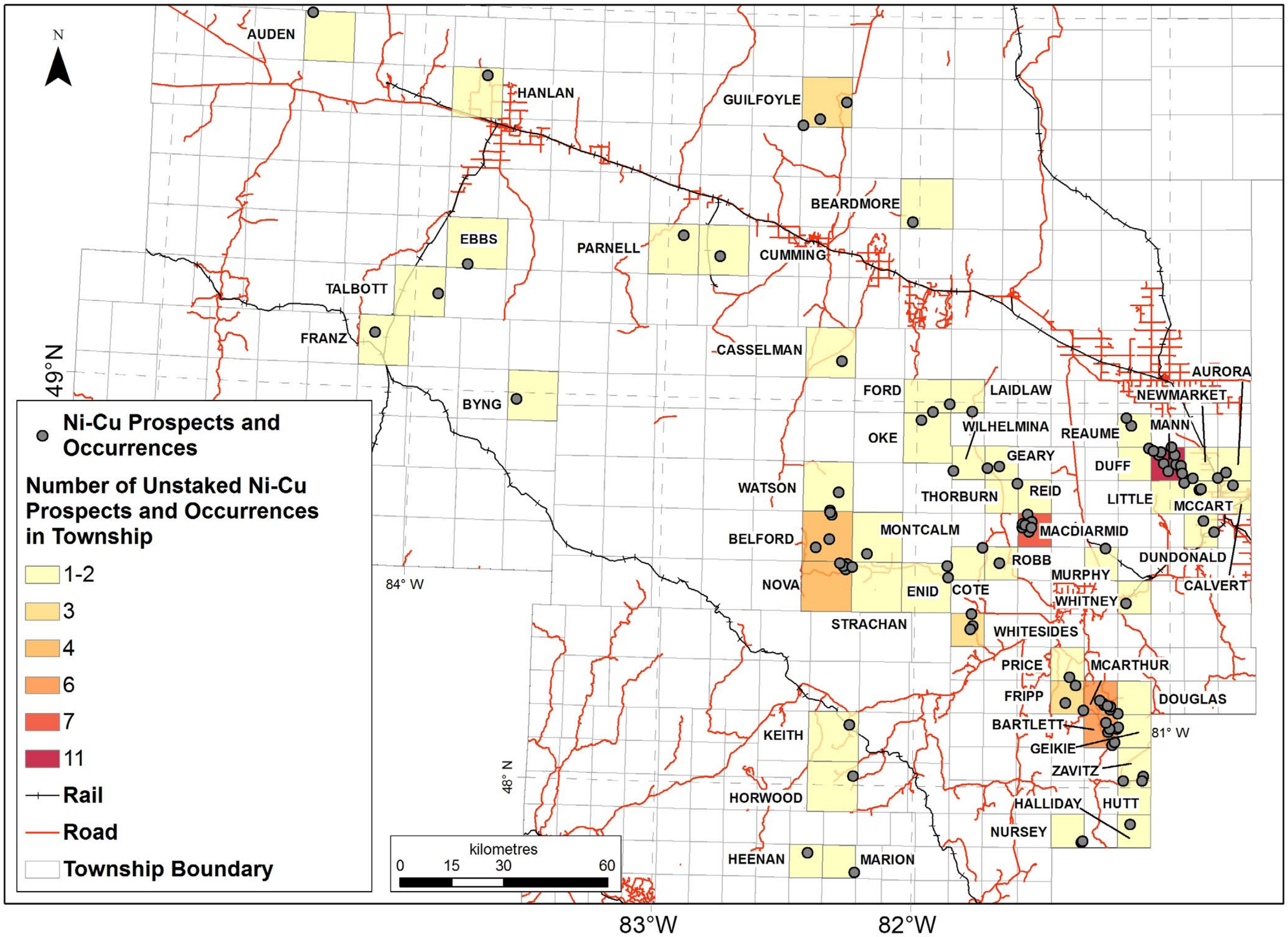

Figure 2. Unstaked nickel-copper occurrences in the Timmins District.

REFERENCES

Ontario Geological Survey 2017. Mineral Deposit Inventory; Ontario Geological Survey, Mineral Deposit Inventory (November 2017 update), online database.

HIGHLIGHTS

- **Potential for lithium and tantalum-rich, rare-element–bearing pegmatite dike swarms in an area with limited exploration history.**
- **Historic mapping has identified several pegmatite targets for further investigation.**

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Potential for Tantalum-Rich Pegmatite Dike Swarms in the Shetland Township Area

INTRODUCTION

Shetland Township is host to tantalum-rich pegmatites for which the Ministry of Northern Development and Mines has no record of previous mineral exploration activity. While the discovery of pegmatite dikes in the area occurred in the 1960s, it was not until the early 2000s that work by the Ontario Geological Survey identified a pegmatite dike containing anomalous concentrations of incompatible elements, including tantalum, rubidium, beryllium, niobium, gallium and tin. Field work in the summer of 2017 by Resident Geologist Program field crews identified an additional pegmatite dike approximately 65 m from the existing occurrence (P. Bousquet, Ontario Geological Survey, personal communication, 2017), which increases the potential for pegmatite dike swarms in the area.

DISCUSSION

Bennett et al. (1967, 1969) mapped pegmatite outcrops in Shetland Township but is was not until the work of Breaks, Selway and Tindle (2002, 2006) that analysis of the outcrops identified they were enriched in tantalum and rare elements. The largest pegmatite is a 3 m wide dike of garnet-biotite-muscovite sodic pegmatite intruding metawacke (MDI42G12SE00001: Mineral Deposit Inventory database (Ontario Geological Survey 2017)). Analysis of a bulk sample of this dike (sample 02-JBS-16-02; Figure 1) identified elevated Ta (113 ppm), Rb (501 ppm), Be (98 ppm), Nb (82 ppm), Ga (29 ppm) and Sn (18 ppm) (Breaks, Selway and Tindle 2006). Breaks, Selway and Tindle (2006) suggest that this pegmatite dike could be derived from a larger pegmatitic granite located 1 km to the north (MDI42G12SE00002; 02-JBS-17), and that the dike could be part of a larger dike swarm (Breaks, Selway and Tindle 2002). Follow up work carried out in the summer of 2017 by P. Bousquet (then District Geologist) identified an additional pegmatite dike 65 m south of the 02-JBS-16-02 bulk sample location. This white pegmatite dike (sample PB-2017-19) contains elevated Ta (110.4 ppm), Rb (264.4 ppm), Be (104.7 ppm), Nb (61.5 ppm), Ga (38.9 ppm) and Sn (>14 ppm). The identification of this additional dike and the similarity of anomalous compositions between samples 02-JBS-16-02 and PB-2017-19 support the suggestion of a larger as yet undefined pegmatite dike swarm(s) associated with the large pegmatitic granite to the north. The suggestion is further supported by the observation of Breaks, Selway and Tindle (2006) that overlapping muscovite and garnet compositions indicate that the pegmatites in Shetland Township may be genetically related to the nearby Lowther pegmatite (MDI42G05NE00004) approximately 9 km to the west. The Lowther pegmatite is currently being explored for lithium, tantalum and beryllium.

Tantalum-Rich Pegmatite Dike Swarms in the Shetland Township Area

At the time of writing, there were no active claims in the vicinity of known pegmatites in Shetland Township, nor is there any assessment work on file with the Resident Geologist Program (it should be noted that while the surface rights in Shetland Township are patented, originally an Algoma Eastern Railroad land grant, the mining rights are held by the Crown and open to staking). Given the proximity of the Shetland pegmatites to the Lowther pegmatite, and the geochemical results from 2017 field work, additional work is recommended. Bennett et al. (1967, 1969) identified numerous other outcrops of pegmatite in the area south of Hearst, including in Shetland Township, that are first order exploration targets, as there is no record of other work by government or industry.

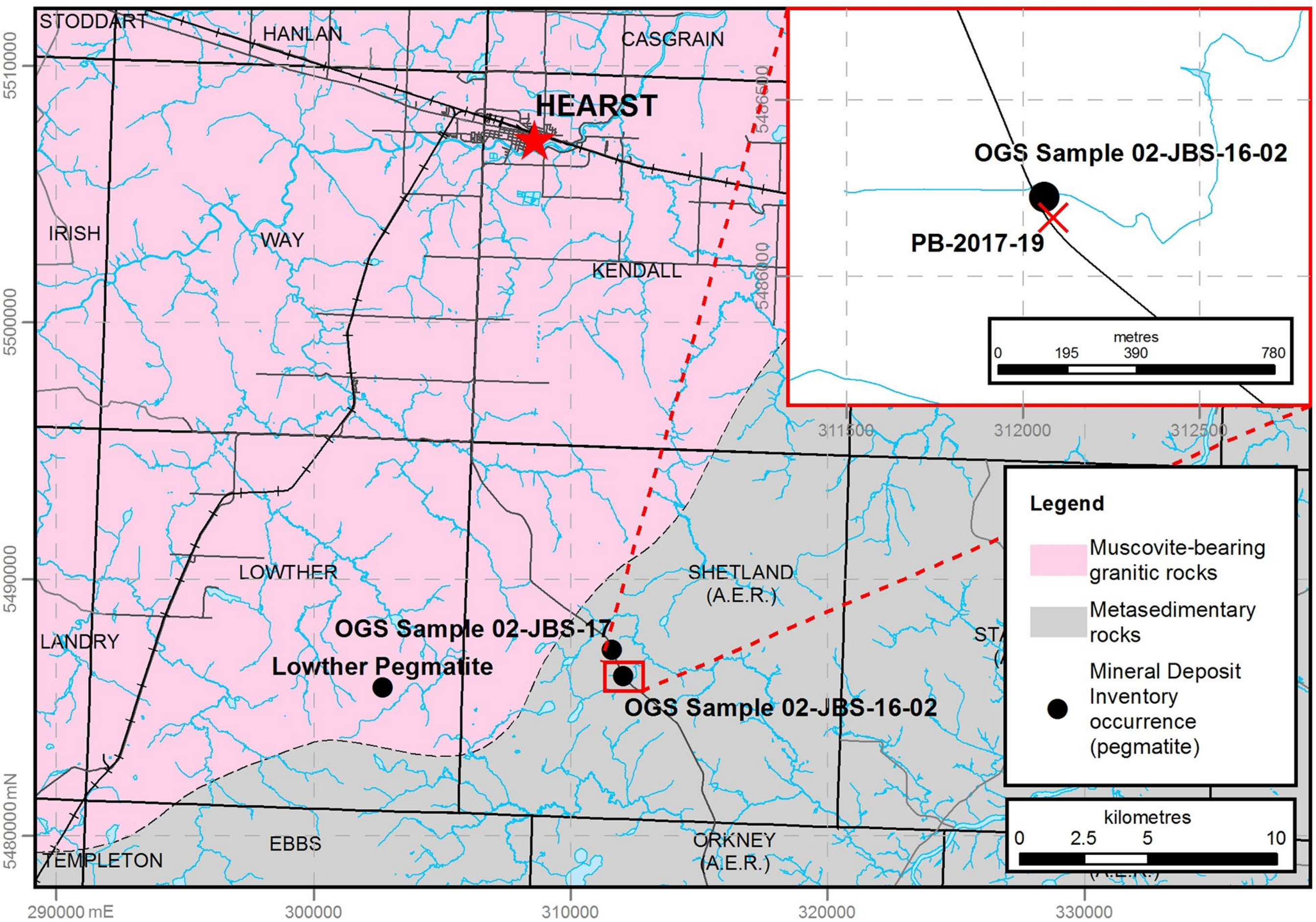

Figure 1. Location of the Lowther pegmatite and samples discussed in text. Geology *from* Ontario Geological Survey (2011). Universal Transverse Mercator (UTM) co-ordinates are provided using North American Datum 1983 (NAD83) in zone 17.

Tantalum-Rich Pegmatite Dike Swarms in the Shetland Township Area

REFERENCES

Bennett, G., Brown, D.D., George P.T. and Leahy, E.J. 1967. Hearst sheet, Geological Compilation Series, Districts of Cochrane and Algoma; Ontario Department of Mines, Preliminary Geological Map P.397, scale 1:126 720.

——— 1969. Hearst–Kapuskasing sheet, Geological Compilation Series, Algoma and Cochrane districts; Ontario Geological Survey, Map 2166, scale 1:253 440.

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

——— 2006. Fertile and peraluminous granites and related rare-element mineralization in pegmatites, north-central and northeastern Superior Province, Ontario; Ontario Geological Survey, Open File Report 6195, 143p.

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

——— 2017. Mineral Deposit Inventory; Ontario Geological Survey, Mineral Deposit Inventory, online database.

HIGHLIGHTS

- **The relatively underexplored and exploited Batchawana greenstone belt has the potential to host cobalt, tungsten and gold.**
- **With the town of Cobalt already undergoing extensive exploration, this area has gone under the radar.**

Cobalt and Tungsten Potential in the Batchawana Greenstone Belt, Tribag Mine Area

The Batchawana greenstone belt (BGB), between 60 and 65 km northwest of Sault Ste. Marie, is host to historic mines of gold, tungsten and cobalt. The Tribag Mine, located in Nicolet and Norberg townships, and the Glenrock occurrence, located in Palmer Township (Figure 1), serve to demonstrate the unexplored potential for these commodities within the greenstone belt. The prospective area is located within the Griffin assemblage of mafic metavolcanic rocks and tholeiitic basalt interlayered with minor felsic tuff and metasedimentary rocks (Jackson and Fyon 1991). The assemblage is bound to the northwest by the Ramsey Gneiss Domain (ca. 2268 to 2267 Ma: Corfu and Grunsky 1987). The only government mapping conducted in this area was compilation-scale work completed in the 1960s; this was in large part because of the poor road access and outcrop exposure. In the last few years, forestry operations have opened up new roads to the area providing opportunity for prospectors to investigate for more base metal and precious metal occurrences.

At the Tribag Mine, historically only 3 main breccia zones were exploited. There are at least 3 PhD theses that describe in detail the geology of these breccia pipes (Armbrust 1967; Belcha 1968; Norman 1977). In 1985, a report by Jonpol Exploration Limited noted that the Tribag property contained at least 5 breccia pipes, with 3 containing a wide variety of metals including copper, silver, molybdenum, tungsten, gold, zinc, lead and antimony (Bradshaw 1985). Scheelite is present as fine to very coarse crystals (Photo 1) with minor wolframite within quartz-carbonate veins within the breccia pipe(s) (Ayer 1981). By 1971, Teck Mining Corporation had extended an existing adit 311 feet and intersected a high-grade tungsten zone. The zone was over 90 feet in length with an average width of 10 feet. This zone was not processed for tungsten as Teck Corporation did not have a mill circuit to recover the tungsten (Ayer 1981). In 1979, Dekalb Mining outlined a tungsten ore shoot open at depth in the West Breccia with 27 600 tons of 0.87% tungsten trioxide (WO_3) (Ayer 1981). Samples collected by the author this past summer confirm that there is a potential for tungsten in the area. An airborne survey conducted by Jonpol Exploration Limited revealed that there are at least 4 additional magnetic anomalies present that could represent additional breccia pipes.

The Glenrock occurrence was discovered in 1952 by O. Bjornaa, who after observing cobalt bloom (Photo 2) on some boulders, completed some trenching. The discovery was optioned to Conwest Exploration Company Limited who completed further stripping, sampling and diamond drilling. Bennett et al. (1993) provide a summary of the exploration history on this occurrence from year of discovery to 1992. Conwest Exploration Company Limited and Glenrock Gold Mines Limited completed a total of 13 trenches and identified 3 veins that contained lenses of cobaltite and pyrite mineralisation. The best assays reported by Conwest were 1.8 ounces gold per ton, 0.5 ounces silver per ton and 13.7% Co, while

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Cobalt and Tungsten Potential in the Batchawana Greenstone Belt

Glenrock obtained a best assay from the trenches of 1.99 ounces gold per ton, 13.4% Cu and 0.04% Co. In 1991 Noranda Exploration Company Limited completed and induced polarization survey and identified the New Glenrock showing, which yielded a best assay of 0.47 ounces gold per ton. A soil geochemistry survey completed in 1992, by Noranda, covered the area and revealed some anomalies.

In 1997 and 1998 Aurogin Resources Ltd. drilled the area and intersected sections of anomalous copper values. These included hole AR98-04 with 8.79% Cu over 0.15 m, 1.25% Cu over 0.15 m, 0.83% Cu over 0.43 m, 1.10% Cu over 0.34 m, 5.40% Cu over 0.25 m and 2.07% Cu over 1.45 m (assessment file 41N01SW2003, Aurogin Resources Ltd. 1998).

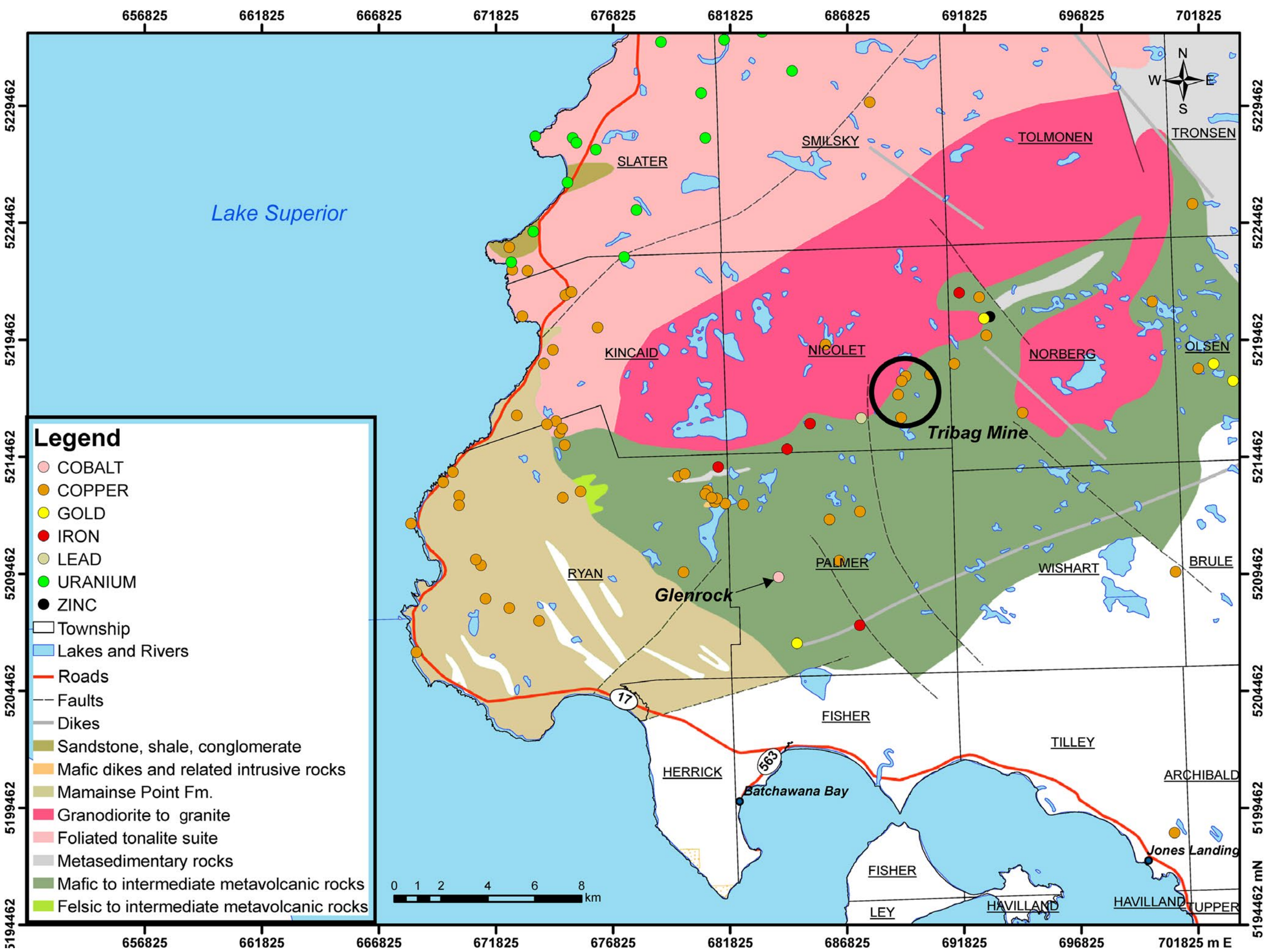

Figure 1. Simplified geological map of the western Batchawana greenstone belt showing the locations of the Tribag Mine and the Glenrock occurrence (geology *from* Grunsky 1987; showings *from* Mineral Deposit Inventory (Ontario Geological Survey (2017)). Universal Transverse Mercator (UTM) co-ordinates are provided using North American Datum 1983 (NAD83) in zone 16.

Cobalt and Tungsten Potential in the Batchawana Greenstone Belt

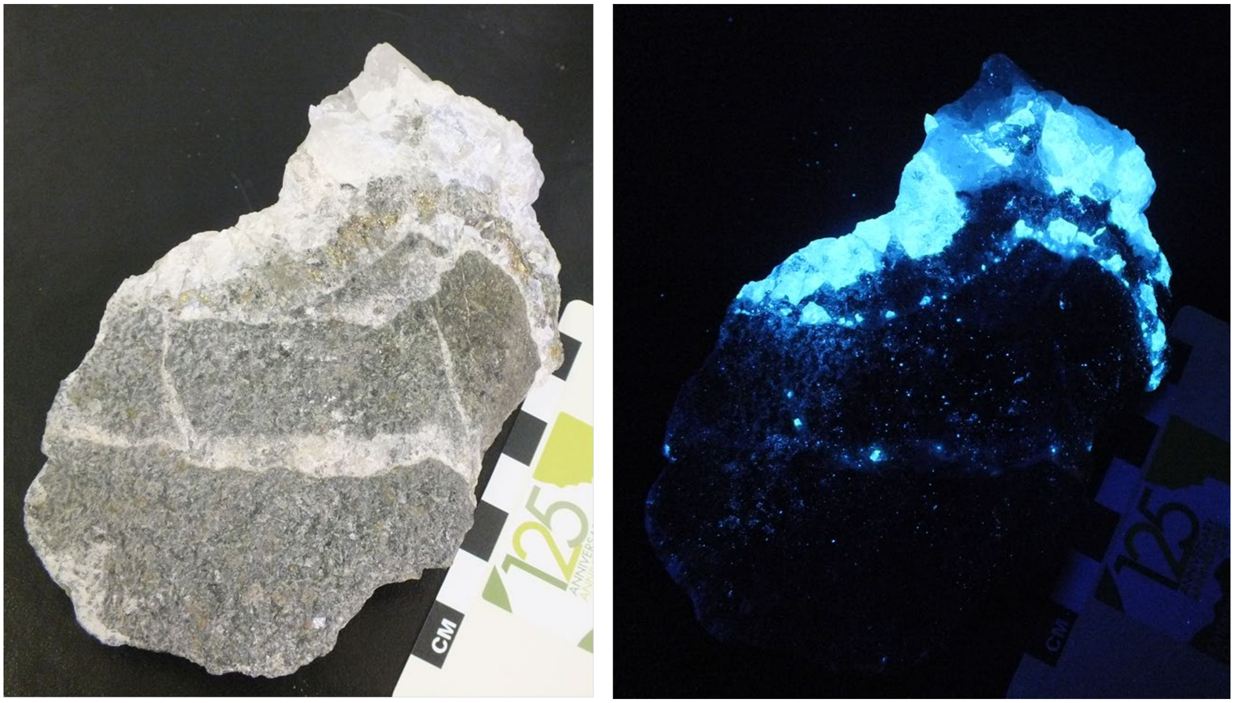

Photo 1. West Breccia quartz-calcite + scheelite vein within a diabase host. Sample pictures were taken in natural light (left) and under ultraviolet light (right) to highlight the distribution of the scheelite mineralisation. Note the scheelite is distributed in the host rock as well as in the quartz veins. The author, Tafa Gomwe, Sault Ste. Marie Acting District Geologist, collected the sample while on a field visit to the Tribag Mine area. The sample is from a waste dump on site.

Photo 2. Cobalt bloom on mafic volcanic rocks near the Glenrock occurrence observed by the author during a field visit.

Cobalt and Tungsten Potential in the Batchawana Greenstone Belt

CONCLUSIONS AND RECOMMENDATION

With the boom in interest around the town of Cobalt, the Batchawana greenstone belt remains an untapped and underexplored area that may have the potential to host both cobalt and tungsten deposits. The logging in the area over the years provides access to previously inaccessible areas. The Tribag Mine and Glenrock occurrences remain underexploited and they provide valuable information that may be used as exploration tools and markers for the area.

REFERENCES

Armbrust, G.A. 1967. Wallrock alteration and paragenesis of the Tribag Mine, Batchawana Bay, Ontario; unpublished PhD thesis, University of Colorado, Boulder, Colorado, 327p.

Aurogin Resources Ltd. 1998. Diamond-drill records, Batchawana property; Sault Ste. Marie District Geologist's Office, Nicolet and Palmer townships, assessment file 41N01SW2003, 79p.

Ayer, J.A. 1981. Dekalb Mining Corporation West Breccia report, Tribag property, Batchawana, Ontario; unpublished report, Sault Ste. Marie District Geologist's office, assessment file 41N01SW0038, 6p.

Bennett, B., Leahy, E.J., Almsley, J. and Hailstone, M. 1993. Sault Ste. Marie Resident Geologist's District 1992; *in* Report of Activities 1992, Resident Geologists, Ontario Geological Survey, Miscellaneous Paper 161, p. 207-231.

Belcha, M. 1968. The origin of the Breton Breccia, Batchawana Bay, Ontario; unpublished PhD thesis, McGill University, Montreal, Quebec, 228p.

Bradshaw, R.J. 1985. Report on the property of Jonpol Exploration Ltd. (formerly known as the Tribag property), Nicolet and Norberg townships, Ontario; unpublished report, Sault Ste. Marie District Geologist's office, assessment file 41N01SW0042, 40p.

Corfu, F. and Grunsky, E.C. 1987. Igneous and tectonic evolution of the Batchawana greenstone belt, Superior Province: A U-Pb zircon and titanite study; Journal of Geology, v.95, p.87-105.

Grunsky, E.C. 1987. Precambrian geology of the Batchawana synoptic project area, Mamainse Point–Pancake Bay sheet, District of Algoma; Ontario Geological Survey, Preliminary Map P.3062, scale 1: 50 000.

Jackson, S.L. and Fyon, A. 1991. The Western Abitibi Subprovince in Ontario; *in* Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part 1, p.405-482.

Norman, D.I. 1977. Geology and geochemistry of the Tribag Mine, Batchawana Bay, Ontario; unpublished PhD thesis, University of Minnesota, Minneapolis, Minnesota, 251p.

Ontario Geological Survey 2017. Mineral Deposit Inventory; Ontario Geological Survey, Mineral Deposit Inventory, online database.

HIGHLIGHTS

- **Geochemically anomalous concentrations of Nb_2O_5 and REE in carbonatite dikes and mineralogy points to a true carbonatitic parent body nearby.**
- **An unknown source of magnetic high east of Chipman Lake.**
- **This is an area that has seen limited historic exploration activity and is currently open for staking.**

The Chipman Lake Carbonatite—A New Rare Earth Element Target

The Chipman Lake Carbonatite Complex (CLCC) is located 55 km northeast of Geraldton in O'Meara Township, and represents a relatively prospective target for rare earth element mineralization. The carbonatite occurrences associated with the CLCC are documented in the Ministry of Northern Development and Mines (MNDM) Mineral Deposit Inventory (MDI) database, as the Loponen (MDI42E16NW00009) and Pitton (MDI42E16NW00008) occurrences.

The CLCC consists of a subcircular diorite to syenodiorite stock (Figure 1), roughly 3 km in diameter (Biczok 1976; Sage 1985), situated within the eastern Wabigoon Subprovince in the Superior Province (Percival and Easton 2007). The CLCC is underlain by Archean mafic to intermediate metavolcanic rocks, mafic and intermediate intrusive rocks, metamorphosed granitic rocks and late Archean granitic rocks, with Proterozoic diabase intrusions, carbonatite and other dike-related rocks (Sage 1985). The carbonatite dikes appear to be restricted to the southern part of Chipman Lake, particularly along the southwestern shore. The carbonatite dikes occur as simple and composite dikes up to 1 m thick which crosscut and fenitize the Archean host rocks (Sage 1985; Platt and Woolley 1990; Royer 1993), as well as numerous float fragments (Sage 1985). Overall, outcrop is locally abundant east of the lake, although extensive sand cover to the west and south drastically limits outcrop availability (Sage 1975).

The carbonatite dikes are spatially associated with a major regional fault (Figure 2), the Big Bay–Ashburton Bay Fault (BB-ABF), which passes through Chipman Lake (Sage 1985). Sage et al. (1983) has called this portion of the BB-ABF the Chipman Lake Fault. The BB-ABF represents one of the growth faults in the Lake Superior region that structurally controlled the development of the Midcontinent Rift (MCR) at approximately 1.1 Ga. A north-northeast extension of this fault, the Trans-Superior Tectonic Zone (TSTZ), is responsible for the spatial localization of alkalic and carbonatite complexes that are temporally related to the MCR (Verplanck et al. 2011).

This association is represented as a string of alkalic and carbonatite complexes that were produced in major, structurally controlled zones along the TSTZ and are generally contemporaneous with the MCR (Sage and Watkinson 1995). The Coldwell complex has a U/Pb age date of 1108±1 Ma (Heaman and Machado 1987); the Killala Lake complex, an Rb/Sr age date of 1050±35 Ma (Bell and Blenkinsop 1980); and the Prairie Lake carbonatite, a U/Pb age date of 1163±3.5 Ma (Rukhlov and Bell 2010), predating the MCR. The Chipman Lake carbonatite dikes have no specific age except for the preliminary K/Ar age of 1022±31 Ma obtained from a fenite (Sage 1985); however, the dikes are considered to be similar in age to nearby alkalic and carbonatite complexes (Platt and Woolley 1990).

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The Chipman Lake Carbonatite—A New Rare Earth Element Target

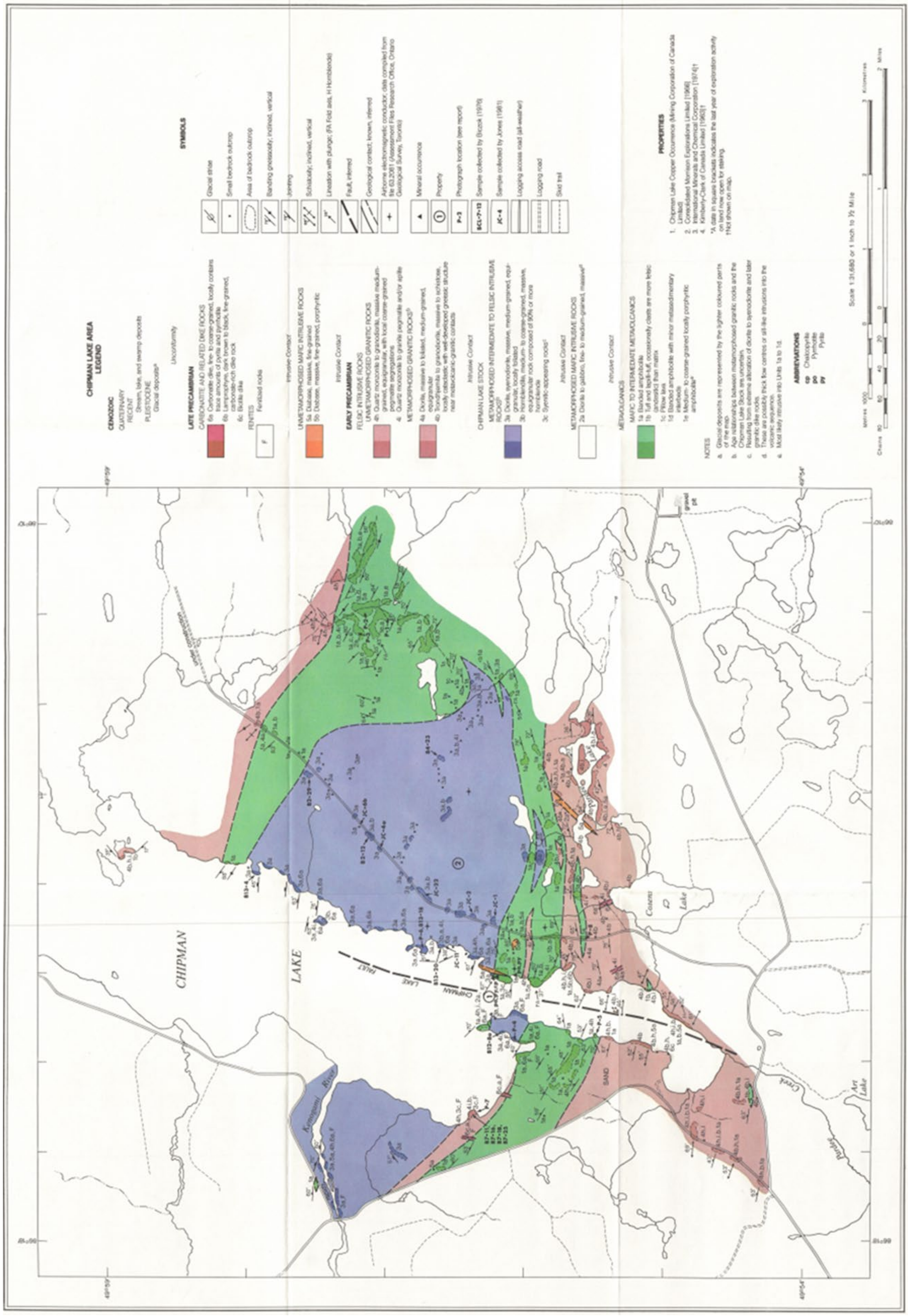

Figure 1. Bedrock geology map showing the location of the Chipman Lake Carbonatite Complex, *from* Sage (1985).

The Chipman Lake Carbonatite—A New Rare Earth Element Target

The known dikes are generally small, ranging from a few centimetres up to 2 m wide, but are dominantly less than 1 m wide (Biczok 1976; Sage 1985; Platt and Woolley 1990). The carbonatite dikes are generally fine to medium grained, white to grey, and may show banding parallel to the margins caused by streaks of dark silicate minerals and grain size variations (Platt and Woolley 1990). They are dominated by dolomite with a gradual compositional change to ankeritic dolomite and commonly host fluoroapatite and albite veinlets, pyrite stringers and/or disseminations and individual calcite grains along grain boundaries and fractures (Platt and Woolley 1990; Graba 2017).

Graba (2017) states that the late-stage fluoroapatite along fractures and grain boundaries is of particular interest as they contain inclusions of very fine-grained cerrusite, synchysite, magnetite and pyrochlore. Approximately 20% of the late-stage veinlets that were studied were found to host rare earth minerals (REE), the rest being barren. Synchysite is the most abundant REE-bearing mineral identified throughout the carbonatite dikes.

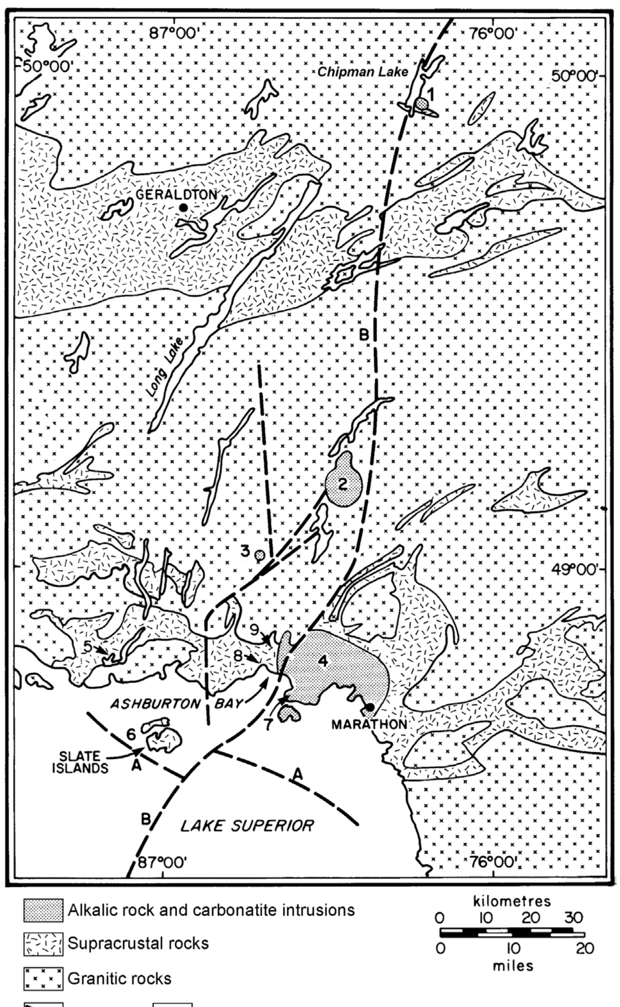

Figure 2. Geological map showing the location of alkalic and carbonatite complexes in the Geraldton–Marathon area and their relationship to the local fault systems (*modified from* Sage 1985; Sage 1991): 1. Chipman Lake carbonatites and fenites; 2. Killala Lake alkalic complex; 3. Prairie Lake carbonatite complex; 4. Coldwell alkalic complex; 5. Gold Range diatreme; 6. Slate Island diatremes; 7. Neys diatreme; 8. Mckeller Creek diatreme; 9. Dead Horse Creek diatreme; A. Michipicoten Island Fault; B. Big Bay–Ashburton Bay Fault and its extrapolated northern extension.

The Chipman Lake Carbonatite—A New Rare Earth Element Target

Graba (2017) classified the Chipman Lake carbonatites as being derived from a true carbonatitic parent without associated silicate rocks. Sage (1985) believes that such a body may be located under Chipman Lake itself; however, the source of the carbonatite dikes has not been determined despite a magnetic anomaly on the southeast shore of Chipman Lake that Satterly in 1968 interpreted as a carbonatite (Sage 1985), but that Sage believes is a magnetite-bearing syenodiorite to diorite stock (Figure 3). The presence of niobium-bearing phases (pyrochlore) coupled with the presence of REE-bearing fluorocarbonates (synchysite) are 2 strong indications of a possible proximal carbonatitic parent body (Graba 2017). The carbonatite classification is based upon a mineralogical–genetic scheme developed by Mitchell (2005) which uses mineralogy to differentiate a carbonatitic parent source from a fluid source derived by magmatic fractionation. This classification scheme can be used as an exploration tool for rare metals, as each genetic type of carbonatite has a distinct geochemical characteristic (Mitchell 2005).

Sage (1985) stated that the concentration of niobium and REEs are too low to be of significant economic interest (8 of the larger carbonate dikes were grab samples and analysed by the Geoscience Laboratories (GeoLabs), Ontario Geological Survey, in Sudbury, for niobium and RREs and returned values from 0.01 to 0.07% Nb_2O_5 and only one detectable REE value: 0.07% cerium); however, their geochemically anomalous concentrations are of interest. In 1993 G. Royer assayed one of the exposed carbonatite dikes. The single sample (93-MGR-5) was analyzed by GeoLabs using ICP-MS and returned anomalous REE values with a caveat: the 1:5000 dilution to facilitate Sr and Nb analysis would degrade precision for all analyzed elements (Royer 1993). Eight samples from 2 diamond-drill holes by G. Royer in 1995 returned values exceeding 650 ppm, with 4 samples exceeding 0.1% Nb (Royer 1995).

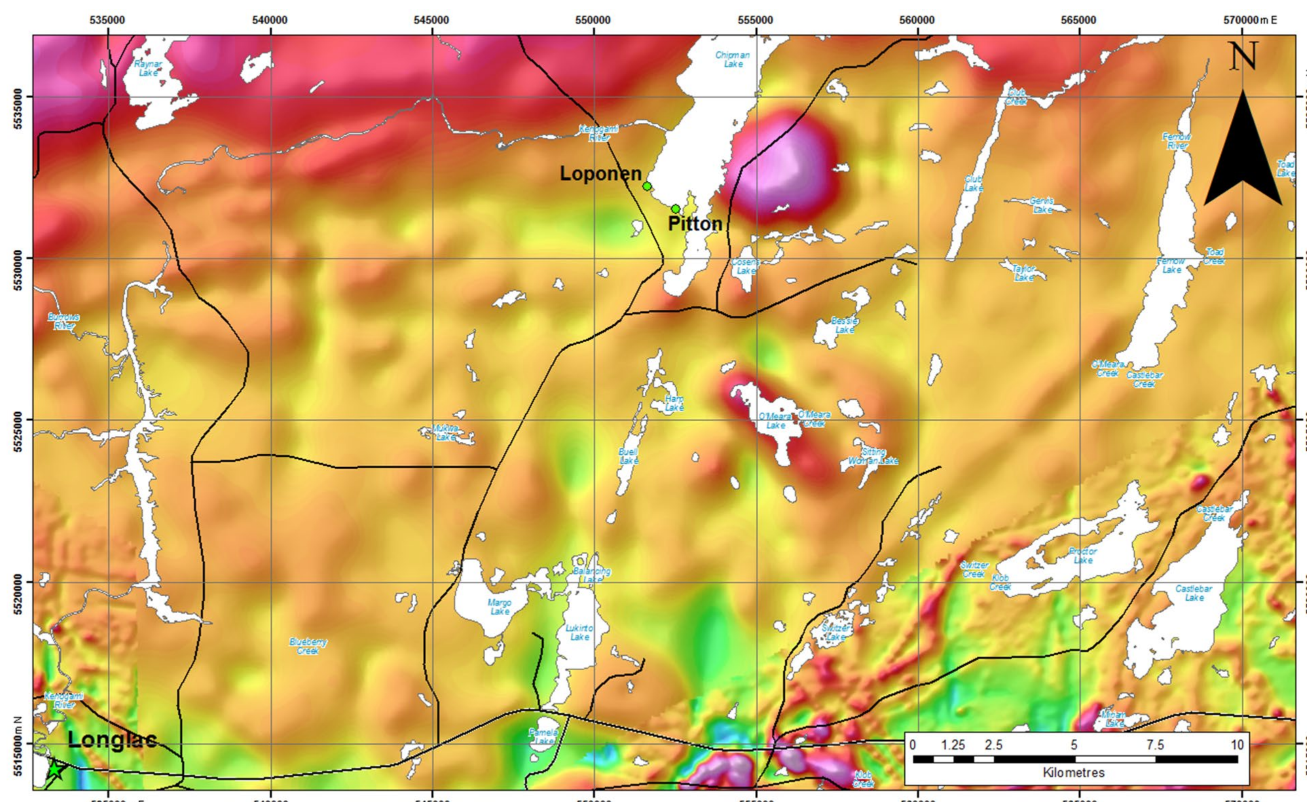

Figure 3. Map of the Chipman Lake area illustrating the anomalous "high" magnetic signature of the Chipman Lake stock (OGS 1999). The labelled green-filled circles denote the location of the Chipman Lake carbonatite occurrences from the Mineral Deposit Inventory (OGS 2017). Universal Transverse Mercator (UTM) co-ordinates provided using North American Datum 1983 (NAD83) in Zone 16.

The Chipman Lake Carbonatite—A New Rare Earth Element Target

			Sample 93-MGR-5			
Element	**Rb**	**Sr**	**Nb**	**Cs**	**Hf**	**Ta**
Concentration (ppm)	2.51	3014.63	1076.96	<0.02	1.43	46.43

Analysis by Geoscience Laboratories, Ministry of Northern Development and Mines, Sudbury, Ontario. Data from assessment file (Royer 1995).

The Chipman Lake Carbonatite Complex and surrounding area remain open for staking at the time of publication. The CLCC is host to anomalous REE mineralized carbonatite dikes, whzich are derived from an unknown parental carbonatite body that could contain higher and potentially economic concentrations of REE mineralization. The complex is spatially and temporally related to other known alkalic and carbonatitic occurrences along the Big Bay–Ashburton Bay Fault that contain REE mineralization. The revaluation of the current OGS-flown aeromagnetic survey data would be prudent, as well, conducting a detailed soil sampling program over the known occurrences using modern analytical services.

REFERENCES

Bell, K. and Blenkinsop, J. 1980. Ages and initial ^{87}Sr-^{86}Sr ratios from alkalic complexes of Ontario; *in* Geoscience Research Grant Program, Summary of Research 1979-1980, Ontario Geological Survey, Miscellaneous Paper 93, p.16-23.

Biczok, J. 1976. The petrography and geochemistry of the Chipman Lake alkaline carbonatite complex; unpublished BSc thesis, Lakehead University, Thunder Bay, Ontario, 128p.

Graba, A. 2017. A mineralogical study of the Chipman Lake carbonatite dykes; unpublished BSc thesis, Lakehead University, Thunder Bay, Ontario, 99p.

Heaman, L.M. and Machado, N. 1987. Isotope geochemistry of the Coldwell alkaline complex: 1. U-Pb studies on accessory minerals; abstract *in* Geological Association of Canada, Annual Meeting 1987, Saskatoon, Saskatchewan, p.54.

Mitchell, R.H. 2005. Carbonatites and carbonatites and carbonatites; The Canadian Mineralogist, v.43, p.2049-2068.

Ontario Geological Survey 1999. Single master gravity and aeromagnetic data for Ontario, Geosoft® format; Ontario Geological Survey, Geophysical Data Set 1036.

——— 2017. Mineral Deposit Inventory; Ontario Geological Survey, Mineral Deposit Inventory, online database.

Percival, J.A. and Easton, R.M. 2007. Geology of the Canadian Shield in Ontario: An update; Ontario Geological Survey, Open File Report 6196, Geological Survey of Canada, Open File 5511, Ontario Power Generation, Report 06819-REP-01200-10158-R00, 65p.

Platt, R.G. and Woolley, A.R. 1990. The carbonatites and fenites of Chipman Lake, Ontario; Canadian Mineralogist, v.28, p.241-250.

Royer, G. 1993. OPAP report on the 1993 exploration programs of the Chipman Lake and Ashmore Township areas; Thunder Bay Resident Geologist's Office, Thunder Bay North District, assessment file, AFRI # 42E16NE0013.

——— 1995. OPAP final report on the Chipman Lake area; Thunder Bay Resident Geologist's Office, Thunder Bay North District, assessment file AFRO # 2.16100, AFRI # 42E16NE0011.

Rukhlov, A.S. and Bell, K. 2010. Geochronology of carbonatites from the Canadian and Baltic shields, and the Canadian Cordillera: Clues to mantle evolution; Mineralogy and Petrology, v.98, p.11-54.

Sage, R.P. 1975. Carbonatite–alkalic complexes; *in* Summary of Field Work 1975, Ontario Geological Survey, Miscellaneous Paper 63, p.58-66.

——— 1985. Geology of carbonatite–alkalic rock complexes in Ontario: Chipman Lake area, districts of Thunder Bay and Cochrane; Ontario Geological Survey, Study 44, 44p.

The Chipman Lake Carbonatite—A New Rare Earth Element Target

——— 1991. Alkalic rock, carbonatite and kimberlite complexes of Ontario, Superior Province; Ontario Geological Survey, Special Volume 4, Part 1, p.683-709.

Sage, R.P., Bathe, D., Wright, W., Chamois, P. and Shewbridge, K. 1983. Precambrian geology of the Chipman Lake area, Thunder Bay and Cochrane districts; Ontario Geological Survey, Preliminary Map P.1068 (Rev.), scale 1:15 840.

Sage, R.P. and Watkinson, D.H. 1995. Alkalic rocks of the Midcontinent Rift; *in* Institute on Lake Superior Geology, 41st Annual Meeting, Marathon, Ontario, Fieldtrip Guidebook, v.41, pt.2a, 74p.

Verplanck, P.L. and Van Gosen, B.S. 2011. Carbonatite and alkaline intrusion-related rare earth element deposits—A deposit model; United States Geological Survey, Open-File Report 2011-1256, 6p.

Kimberlite Targets East of Geraldton

HIGHLIGHTS

- **Newly discovered kimberlite pipes in the Pagwachuan Lake area highlight potential for discovery of additional kimberlite pipes.**
- **Highly prospective magnetic anomalies open for staking resemble those of the Pagwachuan Lake kimberlites.**

Recent kimberlite discoveries in the Caramat area by De Beers (Delgaty et al. 2017; Avery 2017) have unearthed the potential for diamond-bearing kimberlitic rocks in the Long Lake–Pagwachuan Lake area. Re-evaluation of the geophysical data in the Geraldton area (Ontario Geological Survey 2003a, 2003b) has revealed a number of circular magnetic anomalies of varying intensity east of Kenogamisis Lake, shown in white boxes in Figure 1. These anomalies resemble magnetic anomalies on property currently held by De Beers and can be modelled as possible kimberlite targets (i.e., display Keating coefficients). The magnetic anomalies recommended here were not staked at the time of publication.

REFERENCES

Avery, R.W. 2017. Assessment report for claims in the Pagwachuan Project; unpublished report prepared for De Beers Canada Inc., Thunder Bay Resident Geologist's office, Thunder Bay North District, assessment file AFRO# 2.57811, 258p.

Delgaty, J., Fulop, A., Seller, M., Hartley, M., Zayonce, L., Januszczak, N. and Kurszlaukis, S. 2017. Ontario's newest kimberlite cluster—The Pagwachuan cluster; extended abstract, 11th International Kimberlite Conference, Gabarone, Botswana, September 18–22, 2017, 11IKC-4517, 4p.

Ontario Geological Survey 2003a. Ontario airborne geophysical surveys, magnetic and electromagnetic data, grid and profile data, Geosoft® format, Geraldton–Tashota area northwest; Ontario Geological Survey, Geophysical Data Set 1031b.

——— 2003b. Ontario airborne geophysical surveys, magnetic and electromagnetic data, grid and profile data, Geosoft® format, Geraldton–Tashota area southeast; Ontario Geological Survey, Geophysical Data Set 1032b.

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Kimberlite Targets East of Geraldton

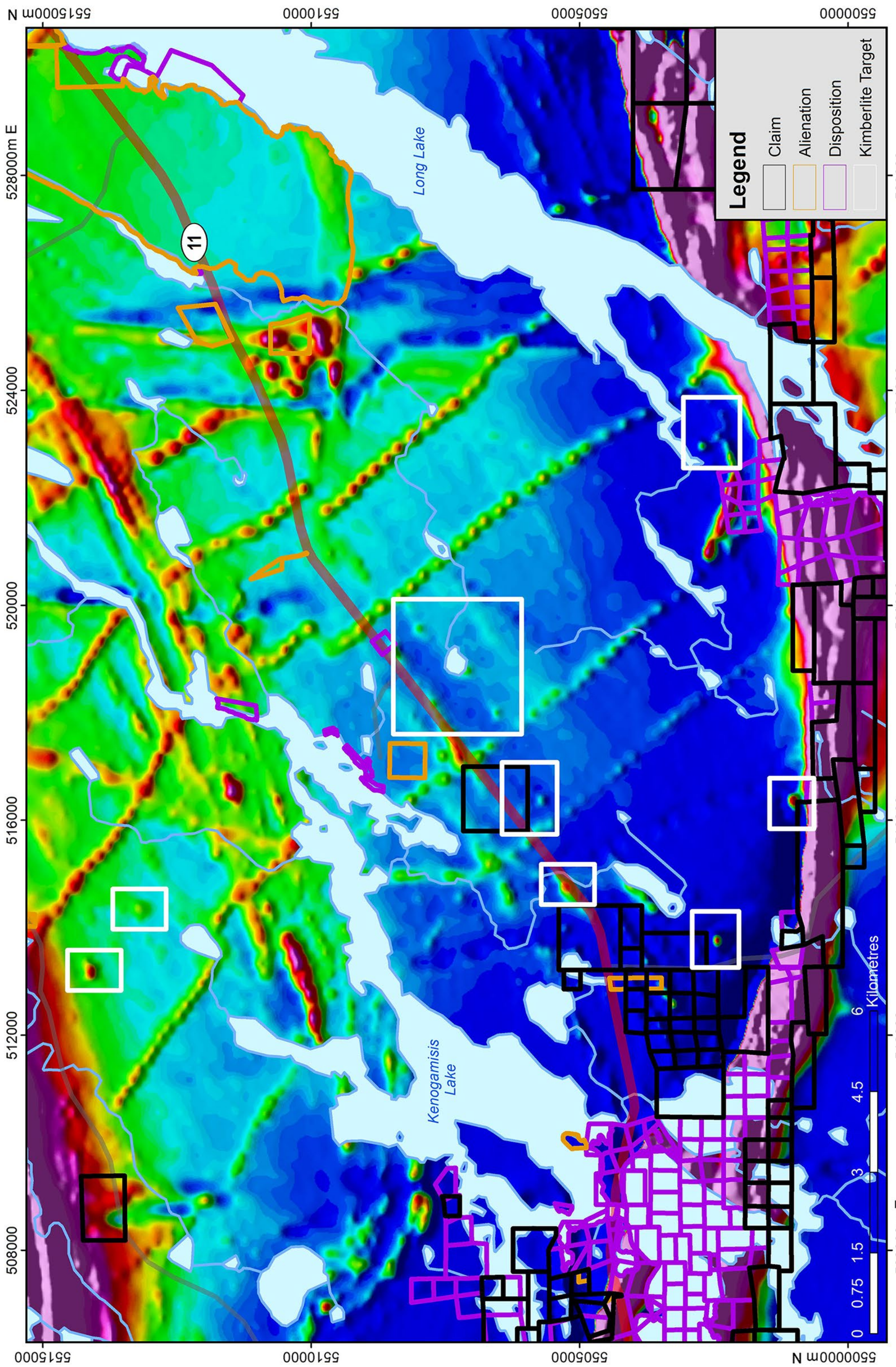

Figure 1. Kimberlite targets (white boxes) in the Geraldton area overlain on an image of the total residual magnetic field. Geophysical data *from* Ontario Geological Survey (2003a, 2003b); Universal Transverse Mercator (UTM) co-ordinates in North American Datum (NAD83), Zone 16. Claim units as of December 8, 2017.

HIGHLIGHTS

- **High-grade PGE assays highlight significant PGE potential in the Bernadine Lake area.**
- **Mineralized gabbroic intrusions along the contact between the Onaman–Tashota greenstone belt and the Onaman pluton remain open for staking.**

Copper-Nickel-Cobalt-Platinum Group Element Potential in the Fullerton Lake Area: Onaman–Tashota Greenstone Belt

Historical and recent exploration activity in the Fullerton Lake area, south and east of Onaman Lake, has highlighted the potential for significant copper, nickel, cobalt and platinum group element (PGE) mineralization within and proximal to the Onaman–Tashota greenstone belt (OTGB). Two specific areas of interest lie within the Fullerton Lake area: the Bernadine Lake and Final Lake areas.

The geology of the Bernadine Lake area was described by Smyk et al. (2005):

> Following regional mapping and compilation, Stott et al. (2002) noted tonalite to granodiorite gneiss with late granitic dikes and amphibolitic inclusions near Bernadine Lake. This lithologic unit is flanked to the south by medium- to fine-grained granodiorite to tonalite. Mafic metavolcanic rocks of the Onaman assemblage, exposed in the Altitude Lake area, become increasingly schistose and amphibolitic near the pluton (ibid.). Kresz (1991) mapped a gabbro along the base of the Onaman assemblage in contact with the felsic, Onaman plutonic rocks to the northeast.
>
> In the vicinity of the initial discovery (Main Showing), the country rock consists of foliated, medium-grained, grey-white, tonalite gneiss. Gneissosity is variable, but generally is north-trending and dips moderately to steeply to the west. The tonalitic gneiss hosts numerous mafic and ultramafic xenoliths (i.e., outcrop-scale) and enclaves (i.e., on the order of tens of metres) and is cut by pink granitic, epidotized pegmatite dikes. There are 3 predominant xenolith types: 1) amphibole-biotite-quartz-feldspar (metasedimentary?) schist; 2) massive, homogeneous, medium-grained gabbro or diorite; and 3) massive, fine-grained ultramafic rocks. Local partial melting has produced magmatitic (brecciated) migmatites with quartzo-feldspathic leucosome veins.
>
> The Main Showing is hosted by a 5 m wide ultramafic enclave that is exposed over 15 m in outcrop. The ultramafic host is fine grained, non-magnetic, foliated, dark green, chloritic, talcose and locally biotitic and feldspathic. It is bounded by tonalitic gneiss and crosscut by quartzo-feldspathic dikelets. Fine-grained, disseminated to net-textured pyrite, chalcopyrite and pentlandite produce small, gossanous patches. Malachite is also present along fracture surface.... Some sulphide minerals also occur in crosscutting felsic dikes and perhaps represent remobilization of primary, ultramafic-hosted mineralization.

Mineralization in the Bernadine Lake area was first discovered by Robert and Marcel Cote in 2004. A drilled grab sample taken by the Cotes returned greater than 6000 ppm Cu, greater than 5000 ppm Ni, 4880 ppb Pd, 616 ppb Pt and 126 ppb Au (Resident Geologist's files, Thunder Bay North District, Thunder Bay). Mapping, prospecting, stripping and channel sampling conducted in the Bernadine Lake area by Sage Gold Inc. in 2009 (Figure 1; cf. Therriault 2010) followed up on copper-nickel-cobalt-PGE mineralization in the area previously explored by the Cotes. Assay results from a prospecting, mapping and channel sampling program by Sage revealed several copper, nickel, cobalt and PGE occurrences. Assay highlights from the 2009 program are included in Table 1 below.

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Cu-Ni-Co-PGEs, Fullerton Lake Area: Onaman–Tashota Greenstone Belt

The Final Lake intrusion lies along the contact between the OTGB and the Onaman pluton, representing a northwest-trending unit of medium- to coarse-grained gabbro and amphibolite (Kresz 1991). The Final Lake intrusion has been subject to periodic exploration since the late 1960s yet hasn't seen significant activity since 2003. Historical exploration activity in the Final Lake area is summarized by Mason et al. (2002) and references therein. Grab samples taken by Resident Geologist Program staff from the Ryan 1 and Ryan 2 zones of the Final Lake intrusion returned values of 3270 ppm Cu, 2747 ppm Ni, 61 ppb Pt, 286 ppb Pd and 61 ppb Au (Resident Geologist's files, Thunder Bay North District, Thunder Bay).

Significant assay results reported by Sage Gold in the Bernadine Lake area, in conjunction with historical results from the Final Lake area, highlight an overlooked area for significant copper, nickel, cobalt and PGE mineralization. The close proximity of units in the Bernadine Lake area and Final Lake intrusion suggest a possible relationship between the mafic-ultramafic units. The Bernadine Lake units may represent sheared enclaves of the Final Lake intrusion or, alternatively, feeder units to the Final Lake intrusion or other intrusions in the OTGB (i.e., Hipel Lake intrusion, Crooked Green gabbro). Refinement of the geological setting of the target intrusions is necessary to establish a structural framework for this idea. Whole rock major and trace element geochemistry can be used as a tool to fingerprint the intrusions and further establish petrogenetic relationships. Exploration strategies may include a surficial sampling program (i.e., soil geochemistry or Mobile Metal Ions (MMI™) survey) to generate

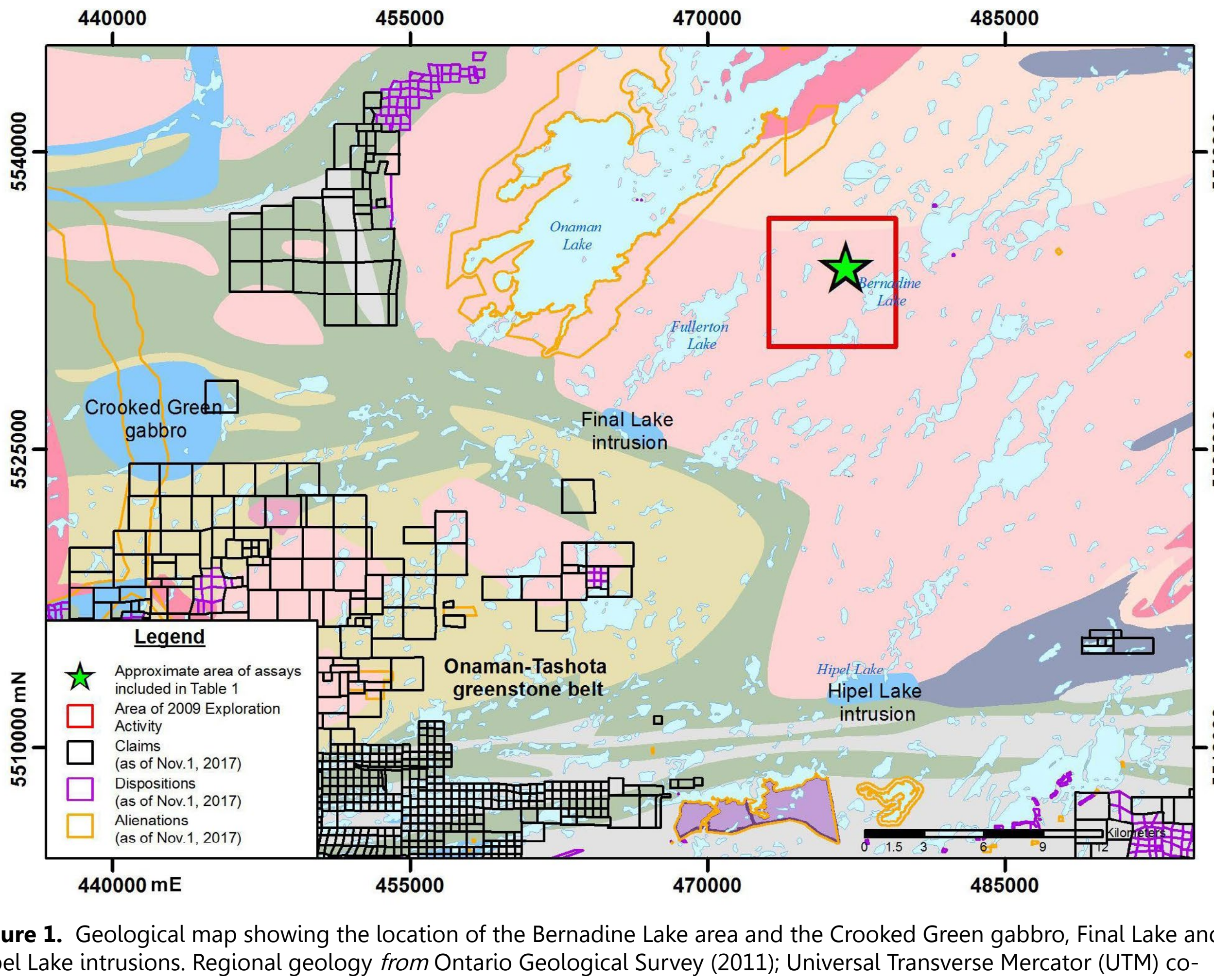

Figure 1. Geological map showing the location of the Bernadine Lake area and the Crooked Green gabbro, Final Lake and Hipel Lake intrusions. Regional geology *from* Ontario Geological Survey (2011); Universal Transverse Mercator (UTM) co-ordinates are provided using North American Datum 1983 (NAD83) in zone 16.

Cu-Ni-Co-PGEs, Fullerton Lake Area: Onaman–Tashota Greenstone Belt

Table 1. Significant assay results from the Bernadine Lake property (*from* Therriault 2010). Significant assays highlighted in bold.

Sample Number	Sample Type	Au (g/t)	Ag (g/t)	Cu (%)	Ni (%)	Cr (%)	Co (%)	Pt (g/t)	Pd (g/t)
09RTB028	Grab	0.14	**14.31**	**1.02**	**0.35**	-	-	0.33	**1.66**
09TWB030	Grab	0.04	-	-	0.24	-	-	0.16	0.87
09TWB031	Grab	0.03	-	-	0.25	-	-	0.31	**1.38**
09RCB517	1.0 m channel	0.11	0.76	0.16	0.13	0.03	0.01	**0.75**	**2.65**
09RCB534	1.0 m channel	0.13	8.64	**0.91**	0.25	0.13	0.02	0.22	**1.11**
09RCB537	1.0 m channel	0.04	5.15	**0.72**	0.29	0.28	0.02	0.31	**1.25**
09RCB287	1.0 m channel	0.04	2.74	**0.66**	0.20	0.55	0.15	0.26	**1.13**
H365568	1.0 m channel	0.08	2.25	0.49	0.28	0.54	-	0.21	0.86
09RCB313	1.0 m channel	0.04	1.51	0.41	**0.39**	0.58	0.18	0.26	0.97
09RCB541	1.0 m channel	0.04	1.49	0.30	0.21	0.07	0.01	0.21	0.82
09RCB310	1.0 m channel	0.03	1.32	0.38	**0.36**	0.96	0.18	0.25	0.90
H365560	1.0 m channel	0.03	1.30	0.34	0.27	0.63	N/A	0.15	0.76
09RCB632	1.0 m channel	0.06	1.27	0.28	0.24	0.78	0.01	0.18	0.77

new and expand old targets in the Fullerton Lake area. Geophysical imagery from a helicopter-borne magnetic–electromagnetic versatile time domain electromagnetic (VTEM™) survey available through the Ontario Assessment File Research Image (AFRI) database (cf. Jagodits (2009) and accompanying maps) may aid in refining structural and lithological elements of the Bernadine Lake property. High-resolution geophysical imagery in the area between Bernadine Lake and Final Lake may reveal new targets and aid in linking the 2 properties. Notable areas of focus would include those not previously prospected by Sage Gold in 2009 as well as the ground between Bernadine Lake and Final Lake. All areas mentioned in this article are open for staking at the time of publication.

REFERENCES

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

Jagodits, F.L. 2009. Report on helicopter-borne magnetic and electromagnetic-VTEM survey, Beardmore Project, Bernadine Lake Block and Silhouette Lake Block, Castlewood Lake and Fullerton Lake townships, Thunder Bay Mining Division, Sage Gold Inc.; unpublished report, Thunder Bay Resident Geologist's office, Thunder Bay North District, assessment file AFRI# 20000005896, 45p.

Kresz, D. 1991. Geology of the Lapierre Lake area, District of Thunder Bay; Ontario Geological Survey, Open File Report 5779, 148p.

Mason, J.K., White, G.D., Scott, J.F., O'Brien, M.S. and Komar, C. 2002. Report of Activities 2001, Resident Geologist Program, Thunder Bay North Regional Resident Geologist Report: Thunder Bay North District; Ontario Geological Survey, Open File Report 6080, 39p.

Cu-Ni-Co-PGEs, Fullerton Lake Area: Onaman–Tashota Greenstone Belt

Smyk, M.C., White, G.D., Magee, M.A. and Komar, C. 2005. Report of Activities 2004, Resident Geologist Program, Thunder Bay North Regional Resident Geologist Report: Thunder Bay North District; Ontario Geological Survey, Open File Report 6147, 37p.

Stott, G.M., Davis, D.W., Parker, J.R. Straub, K.H. and Tomlinson, K.Y. 2002. Geology and tectonostratigraphic assemblages, eastern Wabigoon Subprovince, Ontario; Ontario Geological Survey, Preliminary Map P.3449, or Geological Survey of Canada Open File 4285, scale 1:250 000.

Therriault, R. 2010. Report on work completed on the Bernadine Lake property September 25 to October 20, 2009, Sage Gold Inc.; unpublished report, Thunder Bay Resident Geologist's office, Thunder Bay North District, assessment file AFRI# 20006730, 172p.

Iron Oxide-Copper-Gold (IOCG) and Copper-Nickel-Platinum Group Element Potential Northeast of Thunder Bay

HIGHLIGHTS

- **Lake sediment geochemical anomalies for gold, rare earth elements (REEs), scandium and copper at Little Hicky Lake.**
- **Hematite-bearing pegmatite found near west shore of Little Hicky Lake in vicinity of lake sediment anomalies.**
- **Sulphide mineralized ultramafic float found adjacent to logging road west of Little Hicky Lake.**

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Little Hicky Lake is located in the Quetico Subprovince, approximately 60 km northeast of the city of Thunder Bay. Bedrock in the area immediately surrounding Little Hicky Lake has been mapped as mixed magnetite-bearing syenite to granite and metasedimentary migmatitic gneisses (Metsaranta 2015). Approximately 2 km to the northeast, the Neoarchean Quetico Subprovince rocks are overlain by Mesoproterozoic rocks of the Sibley Group. The Mesoproterozoic Seagull mafic to ultramafic intrusion has been mapped approximately 7.5 km to the north of Little Hicky Lake (Hart 2006). Foliations in the migmatitic rocks strike approximately east-northeast with near-vertical dip. These rocks are crosscut by the north-northwest–striking Greenwich fault, which passes through the centre of Little Hicky Lake. Although the exact timing of deformation associated with this fault has not been determined, it is likely that it was active during the Proterozoic. This conclusion is based on the observations of Scott (1987), who noted the presence of Sibley Group rock fragments in the north-northwest–striking fault zone that hosts the Christianson uranium occurrence at Greenwich Lake. The generalized geology of the Little Hicky Lake area is illustrated on Figure 1.

A recent high-density lake sediment and water survey of the Current Lake area (Dyer and Dell 2016) identified a number of areas with anomalous geochemistry, including a gold-rare earth element-scandium-copper (Au-REE-Sc-Cu) anomaly in the vicinity of Little Hicky Lake (*see* Figures 1 to 4). Reconnaissance prospecting carried out along Hicky Road by staff of the Resident Geologist Program Thunder Bay office during the summer of 2017 resulted in the discovery of an outcrop of hematite-bearing pegmatite near the western shore of Little Hicky Lake (UTM co-ordinates: Zone 16, 358880E 5416981N). The pegmatite contains up to 25% very coarse-grained specular hematite, and this mineralization appears to be associated with a fracture zone that strikes 290° and dips 85° toward the north. This structure coincides with a stream, and parallels a magnetic lineament (low magnetic susceptibility relative to surrounding rocks) that can be seen on Figure 2.

The observation of hematite mineralization in close proximity to the Au-Sc-REE-Cu geochemical anomaly is consistent with the signature for an iron oxide-copper-gold (IOCG) system (Corriveau 2007). Exploration for IOCG (sometimes referred to as Olympic Dam)-type deposits has previously been recommended and/or carried out in the area between Thunder Bay and Armstrong (e.g., Schnieders et al. 2002; Smyk and Franklin 2007). Past exploration has been focussed on Mesoproterozoic hypabyssal intrusions (e.g., English Bay Complex) and north- to northwest-striking faults (e.g., Greenwich fault) that are likely to have been active during the Mesoproterozoic. Based on these factors, further exploration for IOCG-type mineralization is warranted near the Greenwich fault (and associated structures) in the Little Hicky Lake area.

IOCG and Copper-Nickel-PGE Potential Northeast of Thunder Bay

Geochemical data obtained from a sample of the hematite-bearing pegmatite are tabulated below (Table 1). These results show some similarity to analytical data previously reported by Schnieders et al. (2002) for samples collected from a granite-hosted hematite breccia zone located near Roland Lake, approximately 50 km to the northeast of Little Hicky Lake.

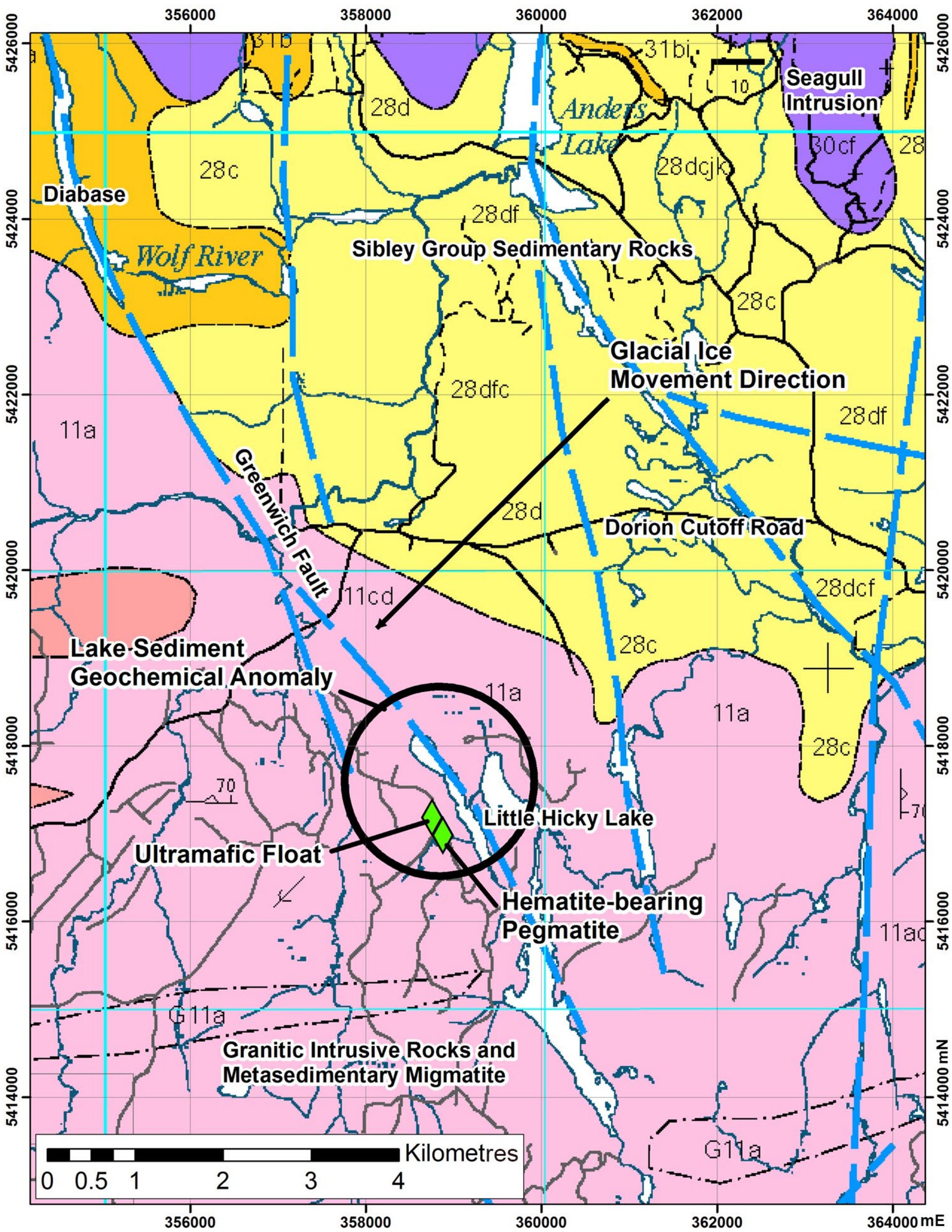

Figure 1. Geological map of the Little Hicky Lake area illustrating the locations (green diamond symbols) of an outcrop of hematite-bearing pegmatite and cobbles of ultramafic float, relative to a lake sediment geochemical anomaly (Au-REE-Sc-Cu) and the approximate glacial ice movement direction (geology *from* Hart 2006). Universal Transverse Mercator (UTM) co-ordinates are provided using North American Datum 1983 (NAD83) in Zone 16.

IOCG and Copper-Nickel-PGE Potential Northeast of Thunder Bay

Table 1. Selected geochemical analyses for a sample of hematite-mineralized pegmatite collected at Little Hicky Lake during the summer of 2017. Analyses performed by OGS Geoscience Laboratories (Resident Geologist's Files, Thunder Bay South District).

Sample	Au ppb	Ba ppm	Ce ppm	Co ppm	Br ppm	Cu ppm	Ga ppm	Fe_2O_3 wt%	La ppm	K_2O wt%	Rb ppm	Sr ppm	Th ppm	U ppm	Zr ppm
LDL	0.6	8	15	1.3	1.2	9	1.3	0.01	7	0.01	0.8	0.8	1.5	1.6	1.8
MP17-WPT014	0.7	1704	100	6.9	1.9	<9	25.1	9.57	58	6.27	123.1	767.2	5.9	<1.6	374.3

Abbreviations: ppb – parts per billion; ppm – parts per million; wt% – weight percent; LDL – lower detection limit.

A second notable observation that was made while doing Hicky Road reconnaissance during the summer of 2017 was the discovery of 3 apparently ultramafic cobbles approximately 250 m northwest of the hematite-bearing pegmatite (UTM co-ordinates: Zone 16, 358759E 5417187N). One of the cobbles contained minor disseminated sulphides, and a sample of this material was collected for assay. Analytical results for this sample are tabulated below in Table 2. Although the sample returned low nickel and copper assay values, it did return an extremely elevated iron value of approximately 25%. This suggests the possibility that this nonmagnetic "ultramafic" rock was also affected by IOCG system alteration. Additional geochemical analyses are planned to evaluate this possibility.

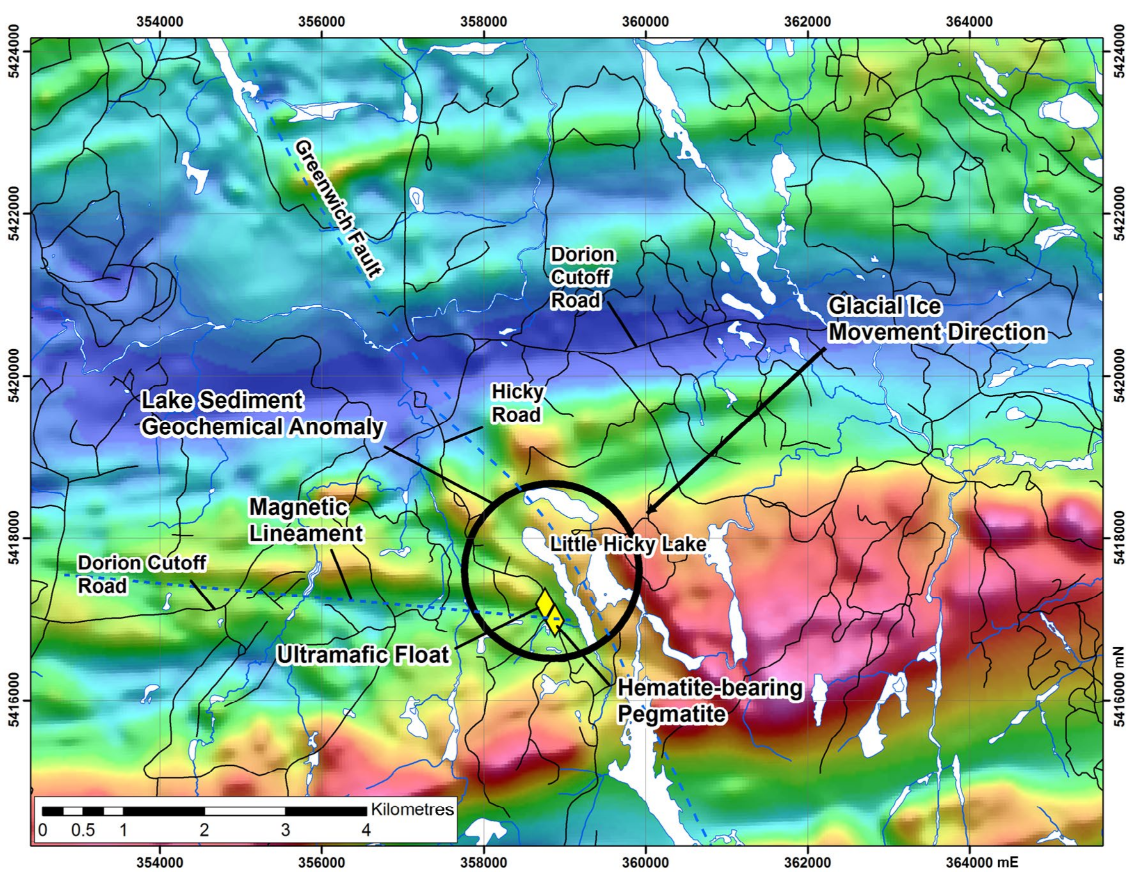

Figure 2. Total field magnetic map of the Little Hicky Lake area (geophysical data *from* Ontario Geological Survey 2004a, 2004b, 2015). UTM co-ordinates are provided using NAD83 in Zone 16.

IOCG and Copper-Nickel-PGE Potential Northeast of Thunder Bay

Table 2. Precious and base metal assay data for a sample of ultramafic float collected at Little Hicky Lake during the summer of 2017. Analyses performed by OGS Geoscience Laboratories (Resident Geologist's Files, Thunder Bay South District).

Sample	Pt ppb	Pd ppb	Au ppb	Ni ppm	Cu ppm	Fe ppm
LDL	0.06	0.14	0.6	2	1	40
MP17-WPT013	RP	RP	RP	56	11	251 629

Abbreviations: ppb – parts per billion; ppm – parts per million; LDL – lower detection limit; RP – results pending.

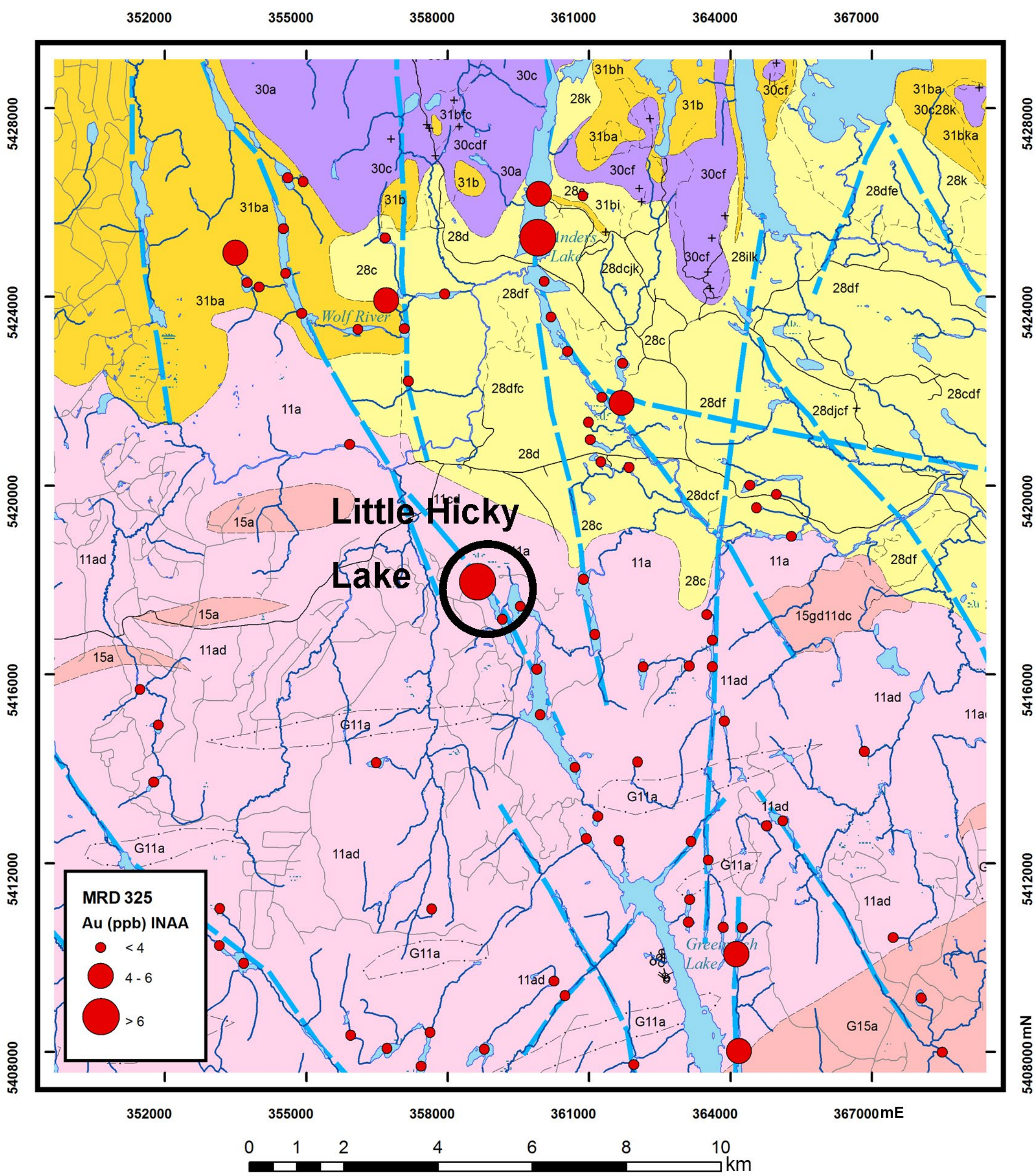

Figure 3. Proportional dot map of Au values obtained from a lake sediment geochemical survey in the Little Hicky Lake area (data *from* Dell and Dyer 2016). Map grid is provided in UTM NAD83 co-ordinates, Zone 16.

IOCG and Copper-Nickel-PGE Potential Northeast of Thunder Bay

The Little Hicky Lake area is largely underlain by thin, discontinuous glacial drift (Barnett, Henry and Babuin 1991). Glacial striae measured by Hart (2006) suggest that the local glacial ice movement direction was toward the southwest. Based on this information, it is probable that the "ultramafic" cobbles were transported from a source located to the northeast, possibly in the area now occupied by Little Hicky Lake. It is also possible that the float originated further up-ice and was sourced from the Seagull intrusion or a previously unrecognized mafic to ultramafic intrusion.

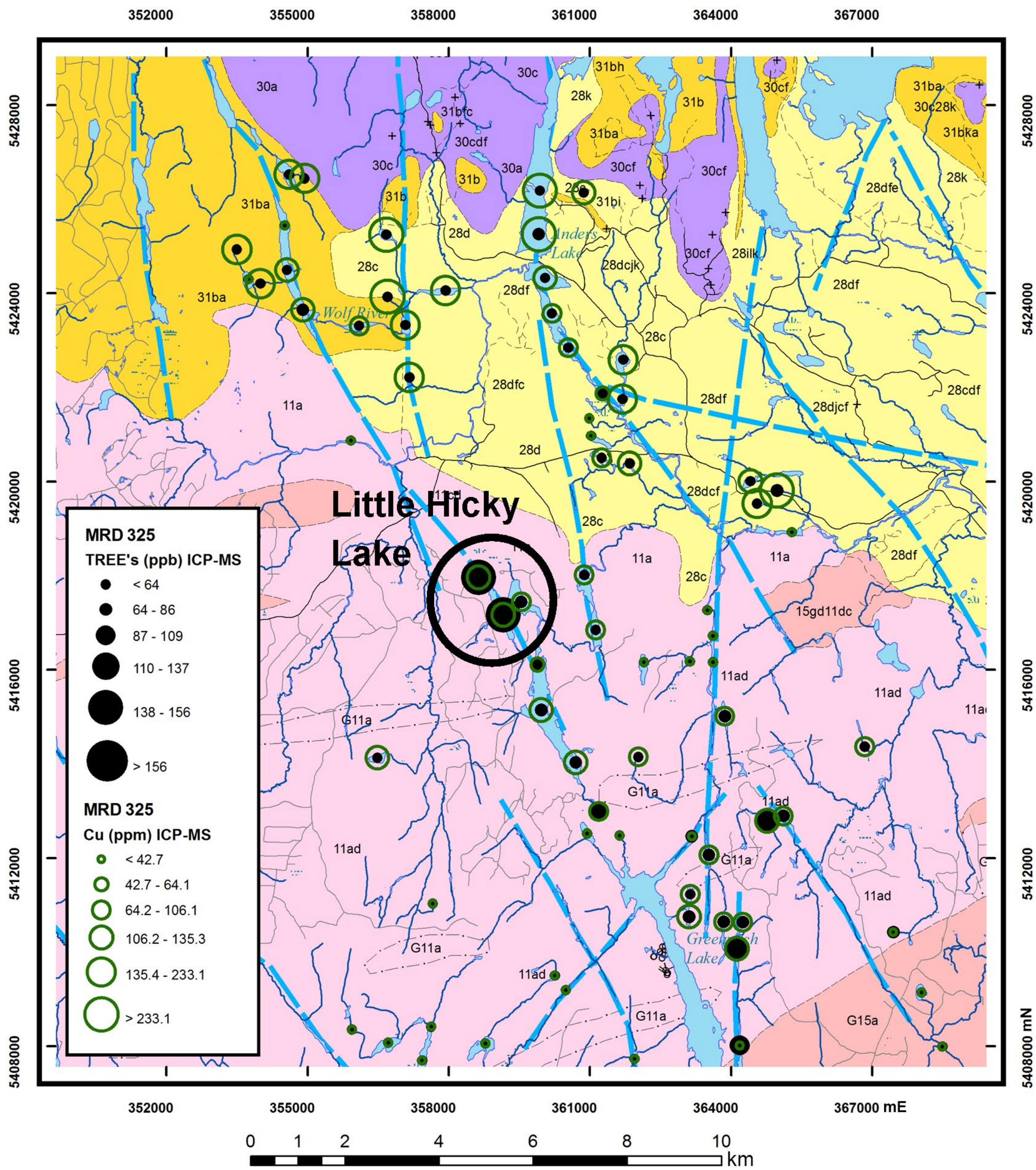

Figure 4. Proportional dot map of total rare earth elements (TREE) and Cu values from a lake sediment geochemical survey in the Little Hicky Lake area (data *from* Dell and Dyer 2016). Map grid is provided in UTM NAD83 co-ordinates, Zone 16.

IOCG and Copper-Nickel-PGE Potential Northeast of Thunder Bay

Regardless of source, the presence of sulphide-mineralized “ultramafic” float in this area suggests that prospecting for mafic to ultramafic intrusion-hosted copper-nickel-PGE mineralization in the area located up-ice (i.e., northeast) from the cobbles is also warranted. It should be noted that the Seagull intrusion is known to host copper-nickel-PGE mineralization, while there are also several additional copper-nickel-PGE mineralized intrusions further to the south between Lone Island Lake and Greenwich Lake (Metsaranta 2015). These intrusions include the Current Lake intrusive complex, which hosts a National Instrument (NI) 43-101-compliant resource and is currently being explored by Rio Tinto Exploration Canada Inc.

The entire area surrounding Little Hicky Lake is open for staking as of November 24, 2017. A number of Ontario Geological Survey geological, geochemical and geophysical maps, reports and data sets are available for the Little Hicky Lake area to assist in the identification of exploration targets. Some of the lake sediment geochemical data from Miscellaneous Release—Data 325 (Dell and Dyer 2016) are illustrated below on Figures 3 and 4. This information can be obtained online through the Ministry of Northern Development and Mines’ OGSEarth and/or GeologyOntario applications, or by contacting the Thunder Bay South Resident Geologist District Office.

REFERENCES

Barnett, P.J., Henry, A.P. and Babuin, D. 1991. Quaternary geology of Ontario, west-central sheet; Ontario Geological Survey, Map 2554, scale 1:1 000 000.

Corriveau, L., 2007. Iron oxide copper–gold deposits: A Canadian perspective; *in* Mineral Deposits of Canada: A Synthesis of Major Deposit-Types, District Metallogeny, the Evolution of Geological Provinces and Exploration Methods, Geological Association of Canada, Mineral Deposits Division, Special Publication no.5, p.307-328.

Dell, K.M. and Dyer, R.D. 2016. Lake sediment and water geochemical data from the Current Lake area, northwestern Ontario; Ontario Geological Survey, Miscellaneous Release—Data 325.

Dyer, R.D. and Dell, K.M. 2016. Current Lake area high-density lake sediment and water survey, northwestern Ontario; Ontario Geological Survey, Open File Report 6311, 99p.

Hart, T.R. 2006. Precambrian geology of the southwest portion of the Nipigon Embayment, northwestern Ontario; Ontario Geological Survey, Preliminary Map P.3580, scale 1:100 000.

Metsaranta, R.T. 2015. Preliminary results from geological mapping of the Quetico Subprovince, the Shebandowan greenstone belt and Proterozoic rocks north of Thunder Bay; *in* Summary of Field Work and Other Activities, 2015, Ontario Geological Survey, Open File Report 6313, p.15-1 to 15-18.

Ontario Geological Survey 2015. Ontario airborne geophysical surveys, magnetic and gamma-ray spectrometric data, grid and profile data (Geosoft® format) and vector data, Lac des Mille Lacs–Nagagami Lake area; Ontario Geological Survey, Geophysical Data Set 1078b.

——— 2004a. Ontario airborne geophysical surveys, magnetic and gamma-ray spectrometric data, grid data (Geosoft® format) and vector data, Lake Nipigon Embayment area; Geophysical Data Set 1047b.

——— 2004b. Ontario airborne geophysical surveys, magnetic and gamma-ray spectrometric data, profile data (Geosoft® format), Lake Nipigon Embayment area; Geophysical Data Set 1047d.

Schnieders, B.R., Scott, J.F., Smyk, M.C., Parker, D.P. and O’Brien, M.S. 2002. Report of Activities 2001, Resident Geologist Program, Thunder Bay South Regional Resident Geologist Report: Thunder Bay South District; Ontario Geological Survey, Open File Report 6081, 45p.

Scott, J.F. 1987. Uranium occurrences of the Thunder Bay–Nipigon–Marathon area; Ontario Geological Survey, Open File Report 5634, 183p.

Smyk, M.C. and Franklin, J.M. 2007. A synopsis of mineral deposits in the Archean and Proterozoic rocks of the Lake Nipigon region, Thunder Bay District, Ontario; Canadian Journal of Earth Sciences v.44, p.1041-1053.

HIGHLIGHTS

- **Large-tonnage, low-grade gold-bearing quartz veins and high-grade, quartz-vein–hosted deposits are known to be associated with northeast-trending structures in the Atikokan area.**
- **Lost Moose Lake area has a cluster of weak to strong lake sediment gold anomalies located along a northeast-trending lineament running parallel to the gold-bearing Bedivere structure.**

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Lost Moose Lake Area Lake Sediment Gold Anomalies near Atikokan

The Lost Moose Lake area has a cluster of weak to strong lake sediment gold anomalies (Dyer 1999a) near a northeast-trending lineament located in the Bedivere Lake area, 52 km northeast of Atikokan, and approximately 130 km northwest of Thunder Bay. The Lost Moose Lake area lake sediment gold anomalies (indicated by the black circle in Figure 1) are recommended for further exploration in light of the new gold discovery, known as the Traxxin occurrence, situated on the Bedivere Lake structure. The Traxxin occurrence was discovered by prospectors M. Frymire, A. Schneider and I. Kerslake of Traxxin Resources in June 2016. The Lost Moose Lake lineament is a feature that lies west of and parallel to the Bedivere Lake structure (*see* Figure 1).

The Bedivere Lake structure was originally recommended for exploration by the Resident Geologist Program in 2008 (Scott et al. 2009) based on a compilation of the following: i) Sandy Lake copper-gold-silver occurrence (Schnieders and Dutka 1985), ii) trenches with anomalous gold values reported in an assessment report by Fern Elizabeth Gold Exploration Ltd. (1989) and iii) lake sediment gold anomalies from a survey by the Ontario Geological Survey (Dyer 1999a, 1999b) that were noted to occur intermittently on or near a northeast-trending structure with a strike length over 12 km. Property examinations by RGP staff and further details about the Traxxin occurrence (previously known as Bedivere Lake) and Sandy Lake gold occurrence (both located on the current Bedivere gold property) can be found in the 2015 and 2008 releases of the Report of Activities for the Thunder Bay South District (Puumala et al. 2016 and Scott et al. 2009, respectively).

In August 2016, Traxxin Resources reported that select grab samples collected from the Bedivere gold property contained visible gold and returned up to 1281 g/t Au (41 ounces gold per ton). Traxxin also reported that a grab sample taken at Sandy Lake, approximately 7.5 km southwest of the Traxxin occurrence, returned an assay of 1.57 g/t Au. The Traxxin occurrence was visited by D. Campbell and G. Paju of the Resident Geologist Program (RGP) in June 2016, confirming the presence of visible gold (Photo 1). Quartz vein material in 2 hand-dug pits were sampled with assay results returning 3.727 ounce gold per ton, 0.695 ounce gold per ton and 0.22 ounce gold per ton. The 2016 discovery was made on the same quartz vein system where sampling by Traxxin Resources and RGP staff in 2015 returned values ranging from anomalous up to 5.21 g/t Au (Puumala et al. 2016).

Lost Moose Lake Area Lake Sediment Gold Anomalies near Atikokan

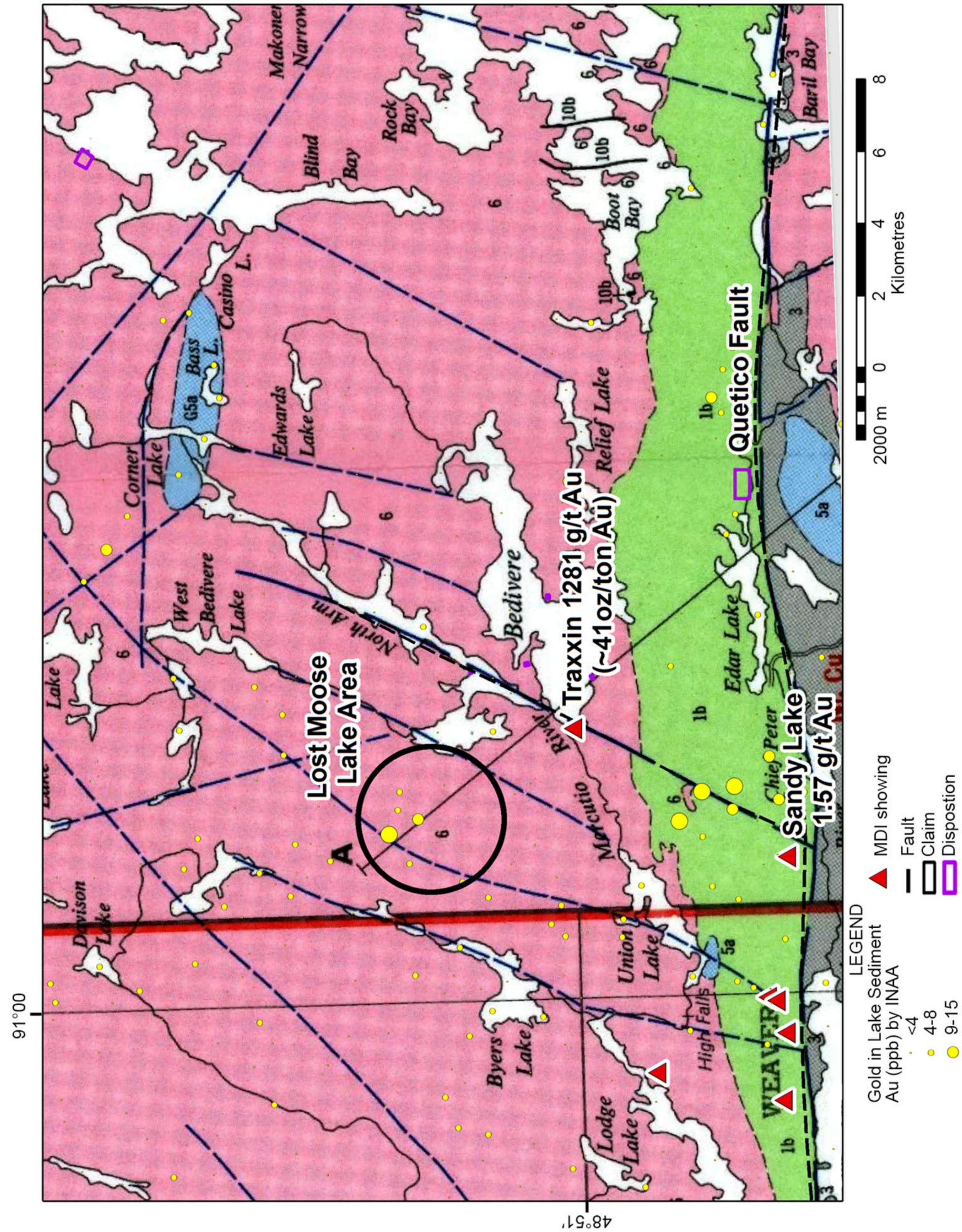

Figure 1. Bedrock geology map of the Bedivere Lake area, near Atikokan, northwestern Ontario (*modified from* Pye and Fenwick 1965). The location of the Lost Moose Lake gold anomalies in lake sediment is shown in the black circle (Dyer 1999a, 1999b). Areas are open for staking as of November 30, 2017. MDI showings were obtained from the Mineral Deposit Inventory (Ontario Geological Survey 2017). The letter A on the map and associated northwest-trending line denotes cross-section available on the original bedrock OGS Compilation Series Map 2065 (Pye and Fenwick 1965).

Lost Moose Lake Area Lake Sediment Gold Anomalies near Atikokan

Photo 1. Grab sample with visible gold from the Traxxin occurrence.

Benton Resources Inc. optioned the Bedivere property from Traxxin Resources in December 2016 (Benton Resources Inc., news release, December 7, 2016). To date, Benton's exploration program includes prospecting, stripping, trenching, channel sampling, geophysics and 14 diamond-drill holes. Benton's stripping and trenching program along the northeast-trending gold-bearing Bedivere Lake structure uncovered an iron carbonate-rich shear zone with quartz stringers containing pyrite and chalcopyrite. Highlights from Phase I of the diamond-drill program are summarized below as follows:

- BED-17-001: 1.50 g/t Au over 14.0 m (including 6.43 g/t Au over 2.0 m)
- BED-17-003: 37.3 g/t Au over 1 m (visible gold)
- BED-17-005: 6.59 g/t Au over 2.7 m
- BED-17-013: 1.07 g/t Au over 22.2 m (including 3.09 g/t Au over 4.0 m)
- BED-17-014: 2.06 g/t Au over 5.0 m

Benton has moved forward with Phase II of its diamond-drill program based on these encouraging results as well as geophysical targets (Benton Resources Inc., news releases, August 31, 2017 and October 17, 2017).

The area of the Lost Moose Lake lineament and associated lake sediment gold anomalies is open for staking as of November 30, 2017. Dyer's (1999a) recommendation for further exploration of the Lost Moose Lake area lake sediment gold anomalies is described below.

> The notable sample sites are 1032, 1079, and 1333 to 1339. The strongest Au anomalies came from 2 adjacent sites (1079 and 1335) with 18 ppb and 11 ppb respectively. The ICP–MS analysis did not corroborate these Au results. Also, no other elements are anomalous, although this may not be detrimental as this is also the case at the Hammond Reef area. The bedrock geology is presumed to consist of granitic rocks (tonalite) with local minor inclusions or rafts of mafic metavolcanic rocks (Irvine 1963). As Schnieders and Dutka (1985) have noted, strongly sheared and carbonatized tonalite (chlorite schists) were often referred to by past geological workers as metavolcanic xenoliths, amphibolite or altered lamprophyre dykes.

Lost Moose Lake Area Lake Sediment Gold Anomalies near Atikokan

While there are no known gold occurrences in the area, it is clear from topographic maps that prominent lineaments (potential fault structures) trending northeast occur in this area. A geological compilation by Pye and Fenwick (1965) shows several interpreted northeast-trending faults through this general area. This lake sediment geochemical signature (gold only) is analogous to the signature of Marmion Lake batholith-type gold occurrences (i.e., Sawbill Bay/Hammond Reef area). The presence of northeast-trending lineaments within the batholith is another key ingredient for this type of gold occurrence. Therefore, based on the geochemical data, and geological and/or structural setting, this area warrants investigation.

REFERENCES

Dyer, R.D. 1999a. Atikokan area high-density lake sediment and water geochemical survey, northwestern Ontario: New Au and PGE exploration targets; Ontario Geological Survey, Open File Report 5986, 79p.

——— 1999b. Lake sediment and water geochemical data from the Atikokan–Lumby Lake area; northwestern Ontario; Ontario Geological Survey, Miscellaneous Release—Data 43

Fern Elizabeth Gold Exploration Ltd. 1989. Manual/mechanical and assay reports, Bedivere Lake; Thunder Bay South Resident Geologist's office, NTS 52B15/SW, assessment file AFRO# 2.12746, 11p.

Irvine, T.N. 1963. Western Lac des Mille Lacs area; Ontario Department of Mines, Geological Report No.12, 24p.

Ontario Geological Survey 2017. Mineral Deposit Inventory; Ontario Geological Survey, Mineral Deposit Inventory, online database.

Puumala, M.A., Campbell, D.A., Tuomi, R.D., Tims, A., Debicki, R.L., Pettigrew, T.K. and Brunelle, M.R. 2016. Report of Activities 2015, Resident Geologist Program, Thunder Bay South Regional Resident Geologist Report: Thunder Bay South District; Ontario Geological Survey, Open File Report 6316, 85p.

Pye, E.G. and Fenwick, K.G. 1965. Atikokan–Lakehead sheet, Kenora, Rainy River and Thunder Bay districts; Ontario Department of Mines Map 2065, Geological Compilation Series, scale 1:253 440.

Schnieders, B.R. and Dutka, R.J. 1985. Property visits and reports of the Atikokan Economic Geologist, 1979–1983, Atikokan Geological Survey; Ontario Geological Survey, Open File Report 5539, 512p.

Scott, J.F., Campbell, D.A., Hinz, P., Komar, C.L. and Brunelle, M.R. 2009. Report of Activities 2008, Resident Geologist Program, Thunder Bay South Regional Resident Geologist Report: Thunder Bay South District; Ontario Geological Survey, Open File Report 6234, 52p.

Rainy River Deposit Atypical Gold-Silver Model

HIGHLIGHTS

- **Rainy River Deposit atypical gold-silver model 2017 highlights.**
- **Atypical pre-orogenic gold-silver setting.**
- **Gold-silver mineralization associated with sulphide minerals.**
- **Sericite and carbonate common alteration minerals with mineralization.**

The Rainy River gold-silver project, situated approximately 55 km northwest of Fort Frances, lies within the southwestern part of the western Wabigoon Subprovince (Figure 1). The discovery and delineation of the economic mineralized zones of this deposit are the result of the success of sustained exploration activity over several years.

The Rainy River deposit is characterized by widespread, disseminated, low-grade and constrained zones of high-grade gold-silver mineralization. This deposit is amenable to large-tonnage, open-pit mining operations, whereas future underground development could target the higher grade mineralized zones (Pelletier 2016).

Recent research by Pelletier (2016), and the Geological Survey of Canada, New Gold Inc. and the Ontario Geological Survey (Pelletier et al. 2015) have contributed to a better understanding of this atypical gold deposit.

DEPOSIT GEOLOGY

The supracrustal rocks that form the Rainy River greenstone belt are typical of geological settings in other parts of the western Wabigoon Subprovince. Pelletier (2016) mentioned that the majority of the mineralization at the Rainy River deposit is hosted in

> …calc-alkaline, coherent or volcaniclastic dacites. The remainder is hosted in tholeiitic basalts. The dacitic package forms an ESE-WNW oriented linear body, bounded to the north, west and south by tholeiitic basalts intercalated with minor mafic-dominated, fine-grained sedimentary rocks. Mineralization is present in both coherent and volcaniclastic dacites, but higher grade mineralization is predominantly hosted in the dacitic tuffs and tuff breccias.

Economic mineralization is localized in calc-alkalic dacite domes, flows and flow breccia, bounded by tholeiitic mafic to intermediate metavolcanic rocks. The porosity of these felsic metavolcanic rocks, which are interpreted to have formed in a subaqueous setting, could have provided the permeability for the circulation of hydrothermal fluids (Pelletier et al. 2015).

The Rainy River deposit comprises a series of stacked, mineralized horizons that, from north to south (i.e., the inferred younging direction), are the 433, HS, ODM/17 and Cap zones (Figure 2). The trend of these mineralized zones generally parallels the contacts of their host metavolcanic units. The strike extent of the mineralized zones can exceed 2000 m. The volcanic successions that host the mineralized zones vary in thickness up to 850 m (Pelletier 2016).

The felsic metavolcanic rocks, which host the majority of mineralization, were formed at *circa* 2717 Ma, determined using U/Pb isotopic dilution thermal ionization mass spectrometry (ID-TIMS). A felsic dike intruded these mineralized dacites at 2693 Ma (U/Pb ID-TIMS), thus constraining

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Rainy River Deposit Atypical Gold-Silver Model

the age of mineralization to between *circa* 2717 Ma and 2693 Ma (P. Mercier-Langevin, Université du Québec, personal communication, February 3, 2017).

DEFORMATION

Up to 5 deformation events have been identified in the Rainy River property (Rankin 2013). Economic mineralization is found in at least 2 prominent features, which, to date, have been observed only in the Rainy River setting and are related to deformation events that occurred either prior to, or during, early D_2 deformation. A bulk of the sulphide and economic mineralization is located in the pervasive S_2 foliation that strikes approximately 120° and dips 50° to 70° to the south. The trend of this inferred bedding-foliation is generally parallel to the contact of the host felsic metavolcanic rocks (*see* Figure 2).

Disseminated low-grade mineralization is found in this S_2 foliation. Higher grade mineralization is locally found within this main foliation, but a majority, according to Pelletier (2016), is located in "a stretching lineation (L_2) oriented 225°/55° [which] on average plunges to the west on the S_2 plane. The high-grade ore shoots within the mineralized bodies are transposed along the L_2 stretching lineation."

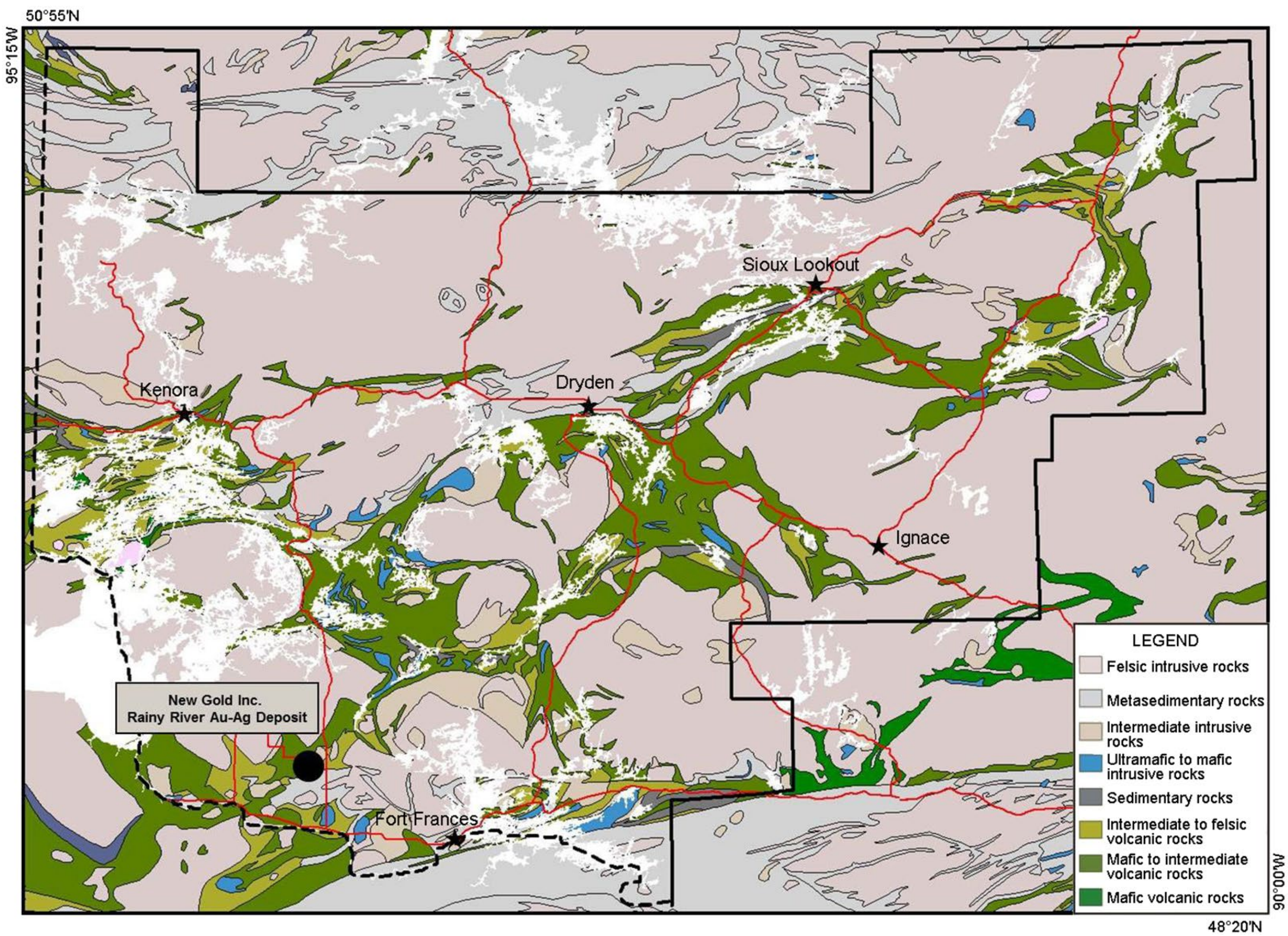

Figure 1. Location of New Gold Inc. Rainy River gold-silver deposit in the Kenora Resident Geologist District (bedrock geology *from* Ontario Geological Survey 2011).

Rainy River Deposit Atypical Gold-Silver Model

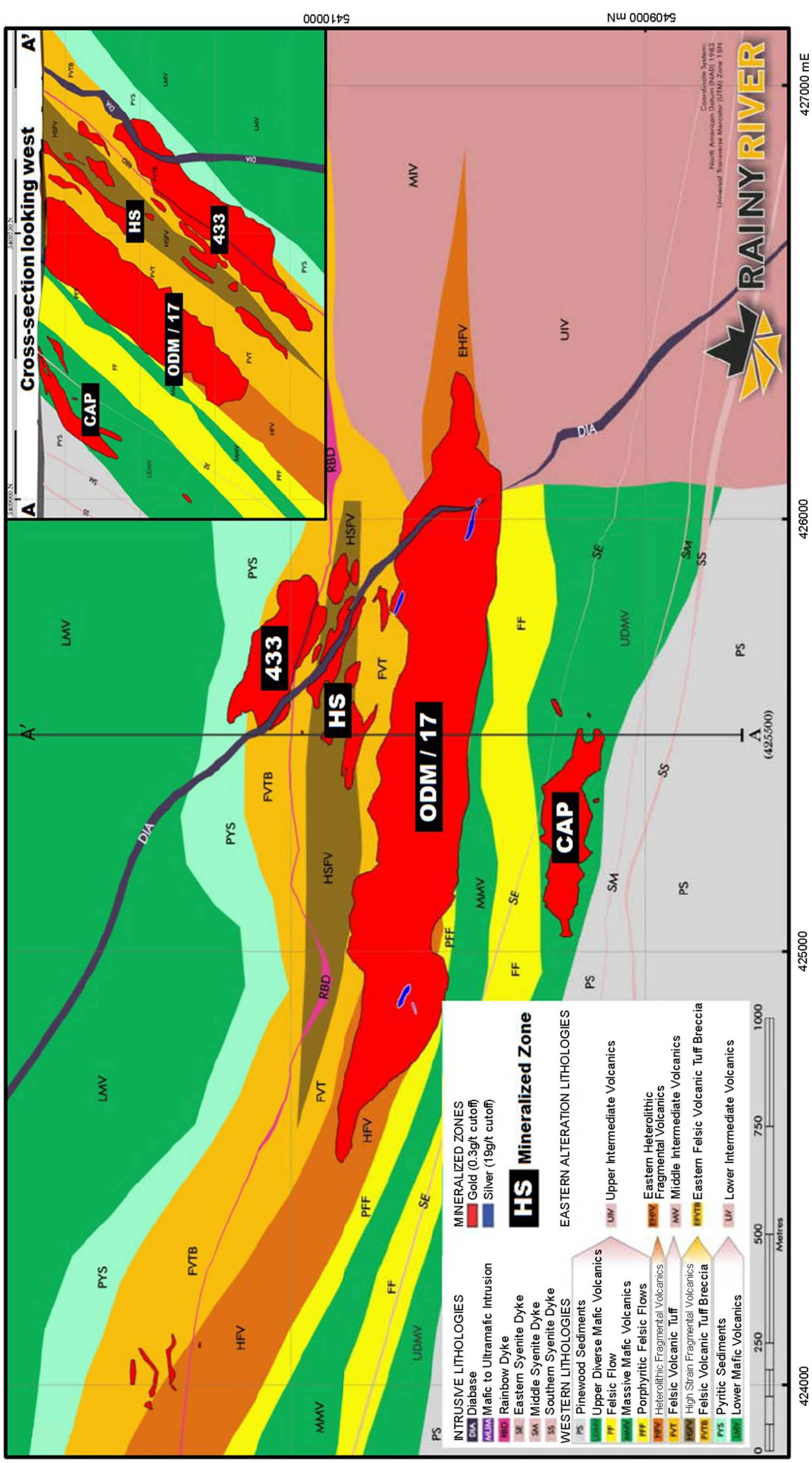

Figure 2. Bedrock geological interpretation, outline of mineralized zones and cross section for the Rainy River gold-silver deposit (*modified from* Hardie et al. 2013, Figures 7-2 and 7-3).

Rainy River Deposit Atypical Gold-Silver Model

Isoclinal D_2 folds present in these metal-bearing zones appear to overprint S_2 foliation. Poulsen (2006) proposed that the elongation of the rock that generated the L_2 stretching lineation could be attributed to this pre-deformation to early D_2 deformation. Additional studies will have to be completed to determine if the folding events are related to the L_2 stretching lineation, but Rankin (2013) has proposed that this lineation could also be associated with fold hinges.

Based on the observations that mineralization is transposed along bedding-parallel S_2 foliation, a stretching L_2 lineation and within the metavolcanic rocks primary porosity, Pelletier (2016) proposed that "the mineralization is a pre- to early D_2 deformation related gold input".

SULPHIDES

There are multiple generations of sulphide mineralization in the Rainy River deposit rocks, but not all sulphide is associated with economic mineralization. Disseminated sulphides vary between 0.5 to 10% by volume in the 433, HS and ODM/17 mineralized zones (*see* Figure 2). The Cap zone also contains disseminated sulphide. The Cap zone is hosted by tholeiitic and calc-alkalic basalts and, in contrast to the felsic metavolcanic rocks, contains greater than 10% by volume disseminated pyrite (Pelletier 2016). Compared to the sulphide content in all the gold-bearing rocks, there is considerably less pyrite in the metavolcanic successions adjacent to these mineralized zones.

Pelletier (2016) mentioned that economic mineralization occurs "mainly as auriferous pyrite, Au- ± Ag-telluride and minor electrum and native gold". The main sulphides associated with gold and silver mineralization are pyrite, sphalerite, chalcopyrite and galena. Pelletier (2016) also commented that the "precipitation of sphalerite, chalcopyrite and galena is probably synchronous to the precipitation of auriferous pyrite". Pyrite-bearing rock from the Rainy River mineralized zones containing chalcopyrite and sphalerite often returned higher gold and silver values than samples without these base-metal sulphides (Pelletier et al. 2015).

Gold-silver mineralization directly associated with sulphide minerals occurs in different styles in the Rainy River deposit rocks. Disseminated pyrite accounts for a majority of the sulphides found in the mineralized zones. Pyrite-sphalerite and occasionally chalcopyrite-galena veinlets and veins, varying in thickness up to 3 cm, are aligned and are sometimes subparallel to the main S_2 foliation. Quartz carbonate pyrite-chalcopyrite-sphalerite veinlets and veins are also found in this foliation, but are often parallel to the L_2 lineation. These quartz carbonate veins can be up to 20 cm wide in the Cap zone, in contrast to those located in the other mineralized zones (Pelletier 2016).

ALTERATION

Hydrothermal fluids could be related to the formation of sulphide and the precipitation of gold. Pelletier (2016) mentioned that the pathways for the circulation of hydrothermal fluids were "controlled by the primary porosity of the volcanic rocks, therefore metal-bearing fluids would have been channelled within the more porous volcaniclastic rock". Silicification, typically associated with circulation of hydrothermal fluids, does not exist within the Rainy River deposit mineralized metavolcanic rocks.

Distinctive minerals associated with hydrothermal alteration are present in the metal-bearing zones. Pelletier (2016) mentioned that these distinctive minerals provide "a link between gold mineralization and the aluminous and potassic, sericite-dominated alteration" and also stated that "the intensity of sericitization directly correlates with the percentage of sulphide". Chlorite, the second-most common alteration mineral, overprints the ubiquitously distributed, dominant sericite within these mineralized zones.

Rainy River Deposit Atypical Gold-Silver Model

Pelletier (2016) also mentioned that the accessory alteration minerals within the mineralized zones are "albite, biotite (almost completely retrograded to chlorite), chloritoid, epidote, Fe-Mg carbonates, kyanite, rutile, and spessartine garnets". Up to 40% of the rock in the mineralized zones comprise these alteration minerals (Wartman 2011).

It is possible that the mineralizing event could have occurred before the tectonic tilting of the volcanic successions. Inferred younging direction is from the 433 zone toward the Cap zone (*see* Figure 2). Base metal content of the mineralized zones is distinctive to this volcanic succession stratigraphy. Pelletier (2016) mentioned that "three dimensional modelling of the metals distribution at the deposit scale shows two dominant metal associations: Au-Ag-As-Pb-Zn ± Cu in the Cap, ODM and upper HS zones, transitioning to Au-Cu ± Zn ± Bi in the lower part of the HS and 433 zones."

Another unusual feature, discussed by Pelletier (2016), related to hydrothermal alteration of the Rainy River deposit is "a series of alteration-related minerals of specific chemistry also outline the different mineralized zones". The basal stratigraphy contains magnesium-rich garnets in the muscovite-chlorite assemblages. This grades upward into a potassic alteration in the muscovite assemblage. The top part of the stratabound mineralized zones is a muscovite-carbonate-chlorite-epidote assemblage (Pelletier 2016).

SIMILAR GEOLOGICAL SETTINGS

Early exploration work performed by Nuinsco Resources Ltd. was based on the premise that the gold mineralization at the Rainy River deposit was shear hosted and epigenetic in origin. This gold-silver–mineralized environment has to now be re-evaluated, based on the proposed gold-rich volcanogenic massive sulphide (Baker 2006) and low-sulphidization epithermal (Wartman 2011) models. Pelletier et al. (2015) and Pelletier (2016) have proposed an atypical setting for the Rainy River deposit, based on a detailed review of the primary and secondary geological controls on mineralizing events, and concluded that it is atypical of common greenstone-hosted orogenic gold and volcanogenic massive sulphide (VMS) deposits.

The mineralizing events at the Rainy River deposit could have formed in a subaqueous setting where the bulk of the economic mineralization consists of disseminated sulphides in a large, sericite-dominated, alteration halo. This mineralizing event occurred prior to or early in the deformation history, contrary to typical greenstone-hosted, orogenic gold settings. The Rainy River deposit is interpreted to have formed sub-seafloor, but the exhalative rocks, which are typically found in a VMS setting, have not been found associated with the mineralized zones. In addition, the Rainy River deposit lacks the colloform-crustiform, low-sulphidation–style vein system with fracture-controlled alteration, as would be expected for an epithermal deposit (Pelletier et al. 2015).

RECOMMENDATIONS FOR EXPLORATION

The regional and property-scale geological setting of the Rainy River project area is comparable to many greenstone-hosted gold and VMS deposit models. The hydrothermal mineralizing events at the Rainy River gold-silver deposit, in contrast to these classic greenstone models, could represent an atypical (or previously undefined) environment where the setting and grade of the metal-bearing zones are controlled by a pre-deformation to early deformation event (Pelletier et al. 2015).

Intermediate to felsic metavolcanic rocks, typically subaqueous dacite, tuff and tuff-breccia, can be prime environments for the existence of primary porosity. The Rainy River setting is distinctive in that the mineralized zones hosted in these volcaniclastic rocks contain widespread disseminated sulphide minerals, sericite and chlorite. The term "orogenic", as used here, is restricted to deposits composed of quartz-carbonate veins and associated wall-rock replacement, associated with compressional or transpressional structures, such as reverse faults and folds. Often these orogenic features, if present in exposures, overprint existing pre-deformation- to early deformation-associated, economic mineralization.

Rainy River Deposit Atypical Gold-Silver Model

Metal-bearing fluids may circulate through permeable zones related to the primary porosity in the rocks. Stratabound permeability is often relatively higher in fragmental rock units, as opposed to massive flows and pillowed basalts. Bedding, foliation and other pre-deformation to early deformation structural features could be channel pathways for fluid circulation. Metal content can be significantly different within these structural pathways.

Common hydrothermal alteration minerals, especially sericite and chlorite, are ubiquitous in the metavolcanic rocks, but higher concentrations of these are often found in the sulphide-bearing, gold-mineralized zones. Distinctive alteration mineral assemblages could be present and are commonly found in stratabound-type mineralizing events. Silicification, a common alteration type associated with circulating hydrothermal fluids, may not be present in the mineralized zones. Identification of these and other alteration types is difficult because of the widespread circulation of hydrothermal fluids.

The high concentration of sulphides and hydrothermal alteration-related minerals, as found in the Rainy River setting, often result in these rocks being susceptible to mechanical erosion and weathering, and the surface expression of the mineralized zones often form topographic "lows". Because the metal-bearing rocks are often buried under overburden, similar to the Rainy River deposit, the exposures peripheral to the mineralized zones are often the only outcrops that can be examined.

At the Rainy River deposit, gold and silver are the dominant indicator elements, whereas zinc and copper are clearly secondary, unlike a typical VMS deposit. When gold values are above 0.325 ppm Au, Pelletier (2015) mentioned that mineralization at the Rainy River deposit is often association with metal concentrations ranging from "1 to 3 ppm for silver, 1 to 7 ppm for bismuth, 34 to 179 ppm for copper, 8 to 79 ppm for lead, 1.9 to 5 ppm for antimony and 87 to 1160.3 ppm for zinc".

Since this base-metal association is common to both deposit models, areas that historically have been examined for VMS mineralization are prime locations to consider for the existence of a geological setting similar to the Rainy River model. A majority of VMS exploration activity conducted in the Kenora District historically occurred when precious metals commodity values were considerably lower than present prices, and often samples were not analyzed for gold.

Groves et al. (2003) mentioned that "these types of [atypical] deposits form prior to the major phase(s) of orogenesis, involving compressional to transpressional deformation, regional metamorphism, and postvolcanic granitoid magmatism during which the orogenic gold deposits form". Quartz veining, which is common in orogenic mineralizing events, could exist in exposures and might overprint pre-existing, metal-bearing zones. A Rainy River model could be applied to local gold occurrences which historically have been examined as typical orogenic deposits. Exploration efforts at these areas should concentrate on rocks that contain higher amounts of disseminated sulphides and hydrothermal alteration minerals and not focus entirely on quartz veining.

Atypical pre-deformation to early deformation gold mineralization may be difficult to recognize because of the overprinting effects of subsequent metamorphism, deformation and alteration. The application of specialized analytical techniques is not always available or practical. Examination of slab-cut rock samples could display unusual sulphide-alteration mineral relationships that could suggest the existence of an atypical mineralizing event. The gold mineralizing events could be associated with a specific formation of sulphide and associated with distinct alteration mineral types. Often, "invisible" gold is found as minute electrum inclusions in pyrite or in pyrite fractures. In the Rainy River setting, quartz-carbonate veins are more commonly found in the mafic, rather than within the felsic, metavolcanic rocks. Paragenetic studies of ore, gangue and alteration minerals could help to elucidate the timing and nature of gold mineralization.

Rainy River Deposit Atypical Gold-Silver Model

REFERENCES

Baker, B. 2006. Rainy River project: Given a new lease on life; The Ontario Prospector, v.11, no.1, p.9-12.

Groves D.I., Goldfarb R.J., Robert, F. and Hart C.J.R. 2003, Gold deposits in metamorphic belts: Overview of current understanding, outstanding problems, future research, and exploration significance; Economic Geology, v.98, p.1-29.

Hardie, C., Runnels, D., Live, P., Daniel, S.E., Ritchie, D.G., Coulson, A., Cole, G., El-Rassi, D., Keogh, C. and Molavi, M. 2014. Feasibility study of the Rainy River project, Ontario, Canada; report prepared for New Gold Inc., by BBA Inc. (in collaboration with AMEC Environment & Infrastructure, SRK Consulting (Canada) Inc. and AMC Mining Consultants (Canada) Inc.); NI 43-101 Technical Report, filed February 14, 2014, with SEDAR®, *see* SEDAR Home Page, 741p.

Pelletier, M. 2016. The Rainy River gold deposit, Wabigoon Subprovince western Ontario: Style, geometry, timing and structural controls on ore distribution and grades; unpublished MSc thesis, Universite Du Quebec, Institut National de la Recherche Scientifique, Centre Eau Terre Environnement, Quebec City, Quebec, 379p.

Pelletier, M., Mercier-Langevin, P., Dube, B., Crick, D., Tolman, J., McNicoll, V.J., Jackson, S.E. and Beakhouse, G.P. 2015. The Rainy River "atypical" Archean Au deposit, western Wabigoon Subprovince, Ontario; *in* Targeted Geoscience Initiative 4: Contributions to the Understanding of Precambrian Lode Gold Deposits and Implications for Exploration, Geological Survey of Canada, Open File 7852, p.193-207.

Poulsen, H.K. 2006. Memorandum regarding July, 2006 visit to the Richardson township property, Emo area, northwestern Ontario; unpublished, confidential report prepared for Rainy River Resources Ltd.

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

Rankin, L.R. 2013. Structural setting of the Rainy River Au mineralization–NW Ontario; unpublished, internal confidential report 2013/08 prepared for Rainy River Resources, 77p.

Wartman, J.M. 2011. Physical volcanology and hydrothermal alteration of the Rainy River gold project, northwest Ontario; unpublished MSc thesis, University of Minnesota, Minneapolis, Minnesota, 154p.

HIGHLIGHTS

- **Recent survey combined with previously published aeromagnetic surveys re-emphasizes the mineral potential of the Uchi–English River Subprovince boundary area in NTS areas 52 K/15 and 52 K/16.**
- **Great mineralization potential in the English River Subprovince and along the Uchi–English River Subprovince boundary.**
- **This is an area that is lacking comprehensive geological mapping, has limited exploration and is currently open for staking.**

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Recently Published Aeromagnetic Survey Re-emphasizes the Mineral Potential Along the Uchi–English River Subprovince Boundary (NTS 52 K/15–16), Northwestern Ontario

In 2016, the Ontario Geological Survey completed an airborne magnetic gradiometer and gamma-ray spectrometer geophysical survey covering the Winnipeg River and English River Subprovinces, extending from the Manitoba–Ontario border to the Sioux Lookout–Savant Lake area. Interpretation of this recent survey combined with previously published aeromagnetic surveys re-emphasizes the mineral potential of the Uchi–English River Subprovince boundary area in National Topographic System (NTS) areas 52 K/15 and 52 K/16 (OGS 1991; OGS 2017a, 2017b).

North of the subprovince boundary, the supracrustal rocks of the Uchi Subprovince are characterised by felsic to mafic volcanic rocks, quartz monzonites, tonalities and peraluminous granites to granodiorites. The Sydney Lake fault forms the boundary between the 2 subprovinces and can be traced approximately 250 km from near Lake Winnipeg in Manitoba to Pakwash Lake, Ontario. From there it can be traced discontinuously for another 200 km to the east, where it is known as the Lake St. Joseph fault (Lichtblau et al. 2013). South of the boundary, the English River assemblage includes metasedimentary migmatites, fine-grained clastic and siliclastic rocks intruded by the peraluminous granite and granodiorite of the Bluffly Lake and Sharpe Lake batholiths.

Historically, exploration has been limited to the immediate vicinity of the Uchi–English River Subprovince boundary, mainly targeting aeromagnetic anomalies of iron occurrences. Two historic iron deposits are known within the immediate area (with non-National Instrument (NI) 43-101 compliant resources): 1) the Ogani deposit, with 100 million tons @ 21.6% Fe (Shklanka 1968, Table 14), and 2) the Papaonga deposit, with 13.5 million tons @ 31.06% Fe (MDI52K16NE00006, OGS 2017c). Despite the early discoveries of iron formation within the region, exploration work faded. No significant mineralized occurrences are known to exist in the English River metasedimentary rocks in this area.

Mineralization potential in the English River Subprovince and along the Uchi–English River Subprovince boundary includes

- Algoma-type banded iron formation (BIF),
- rare metal pegmatites,
- cobalt-copper-nickel-platinum group elements in mafic-ultramafic intrusions in the English River Subprovince (as highlighted by Lichtblau and Ravnaas 2017),
- greenstone-hosted lode gold deposits, and
- “atypical” stockwork and replacement-style gold mineralization hosted within highly deformed and metamorphosed metasedimentary rocks and paragneiss, as at Goldcorp Incorporated’s Éléonore Mine in Quebec (Beausoleil et al. 2014).

Mineral Potential, Uchi–English River Subprovince Boundary

The re-evaluation of the McCombe pegmatite by Breaks, Selway and Tindle (2001) in the Root Lake area found significant lithium and tantalum mineralization (Figure 1). Storey et al. (2000) highlighted the rare metal exploration potential in pegmatitic rocks hosted in mafic metavolcanic rocks proximal to the English River Subprovince boundary within this region. Currently, Ardiden Limited holds the McCombe deposit (with a non-NI 43-101 compliant resource of 2.3 million tons @ 1.3% Li_2O; Mulligan 1965). Frontline Gold Corp. recently secured an option to acquire 6 lithium mineral claims 12 km north of the subprovince boundary.

The new high-resolution aeromagnetic survey (OGS 2017a, 2017b) makes structural interpretation more readily achievable. In particular, the previously unknown Wesley Lake Structure is a very noticeable feature that truncates the predominant east-southeast–trending aeromagnetic fabric of the Bluffy Lake batholith (Figure 2). This structure can be cross-correlated with satellite imagery, gravity geophysics (Barlow, Gupta and Wadge 1976) and the 2nd vertical derivative of the residual magnetic field. Grab samples from banded iron formations in the Sandy Point and Dole Lake deformation zones returned assay values up to 0.55 ounces per ton Au (Lichtblau et al. 2005).

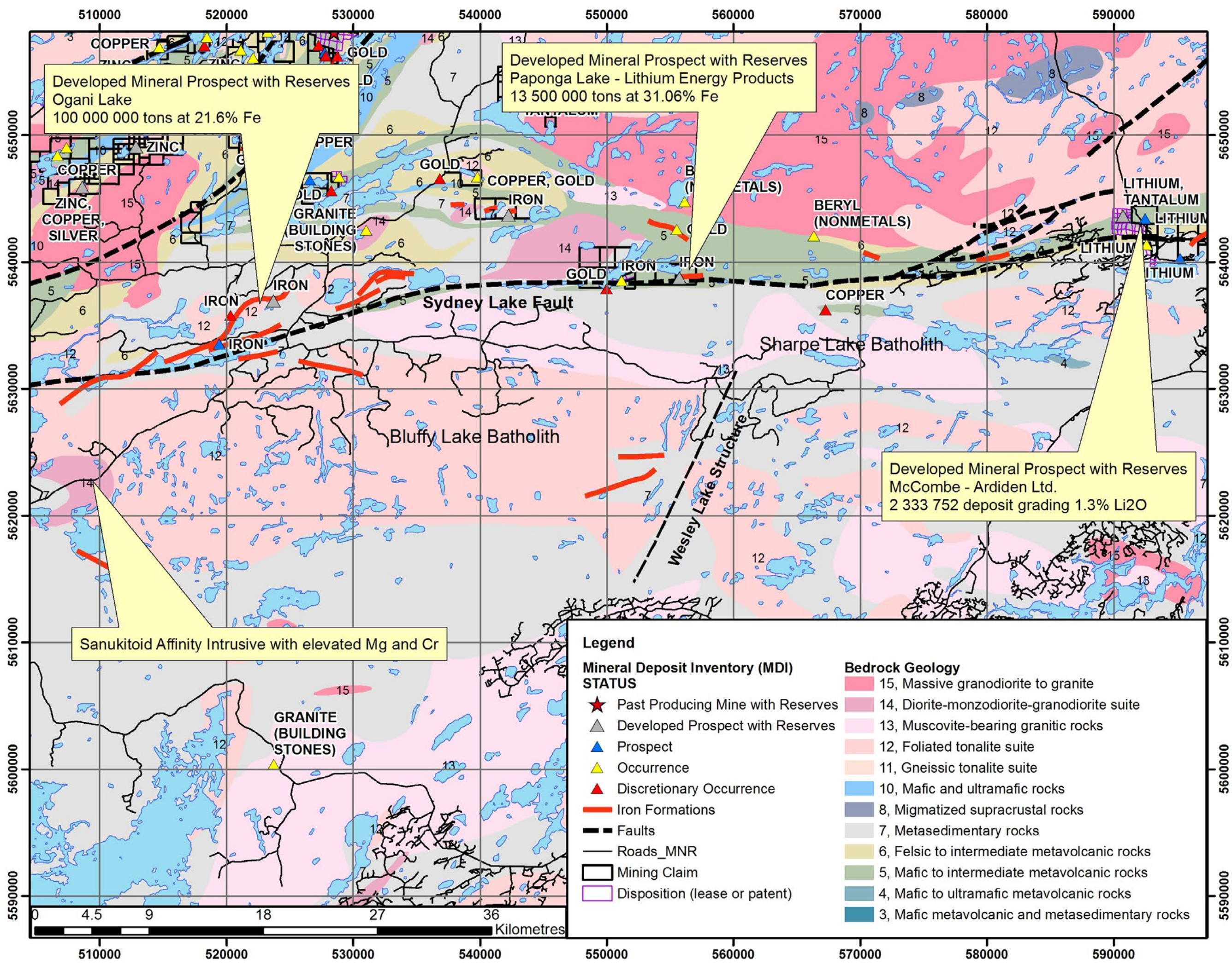

Figure 1. Bedrock geology, locations of mineral occurrences and claim boundaries along the Uchi–English River Subprovince boundary. (Claim information current to October 1, 2017; bedrock geology *from* Ontario Geological Survey 2011; Universal Transverse Mercator (UTM) co-ordinates in North American Datum 1983 (NAD83), Zone 15.)

Mineral Potential, Uchi–English River Subprovince Boundary

Comparison of the aeromagnetic surveys and the known bedrock mapping shows there is significantly more complexity in the bedrock that is not currently recognized. Also of particular interest, the strong aeromagnetic signatures correlate well with known BIF occurrences in the region thus suggesting the potential for more BIF discoveries in areas of previously untested high magnetic signatures.

Previous workers (Breaks et al. 1976; Zeng and Calvert 2006) have indicated that the Sydney Lake fault may only extend from 6 to 13 km in depth, but the presence of intrusions of sanukitoid affinity suggest deeper tapping structures exist in the area. A diorite intrusion with elevated magnesium and chromium, mapped as a mafic satellite phase of the Bluffy Lake batholith, may be one of these sanukitoids, as is the Pakwash Lake stock (Lichtblau et al. 2013). Late mantle-derived plutons (such as sanukitoids) may be associated with Archean lode gold deposits (Beakhouse 2007).

In general, the lack of full geological mapping, limited exploration and open ground make this a high priority target area. A useful guideline for rare metal pegmatites was described by Breaks, Selway and Tindle (2003) which can be consulted for pegmatite exploration.

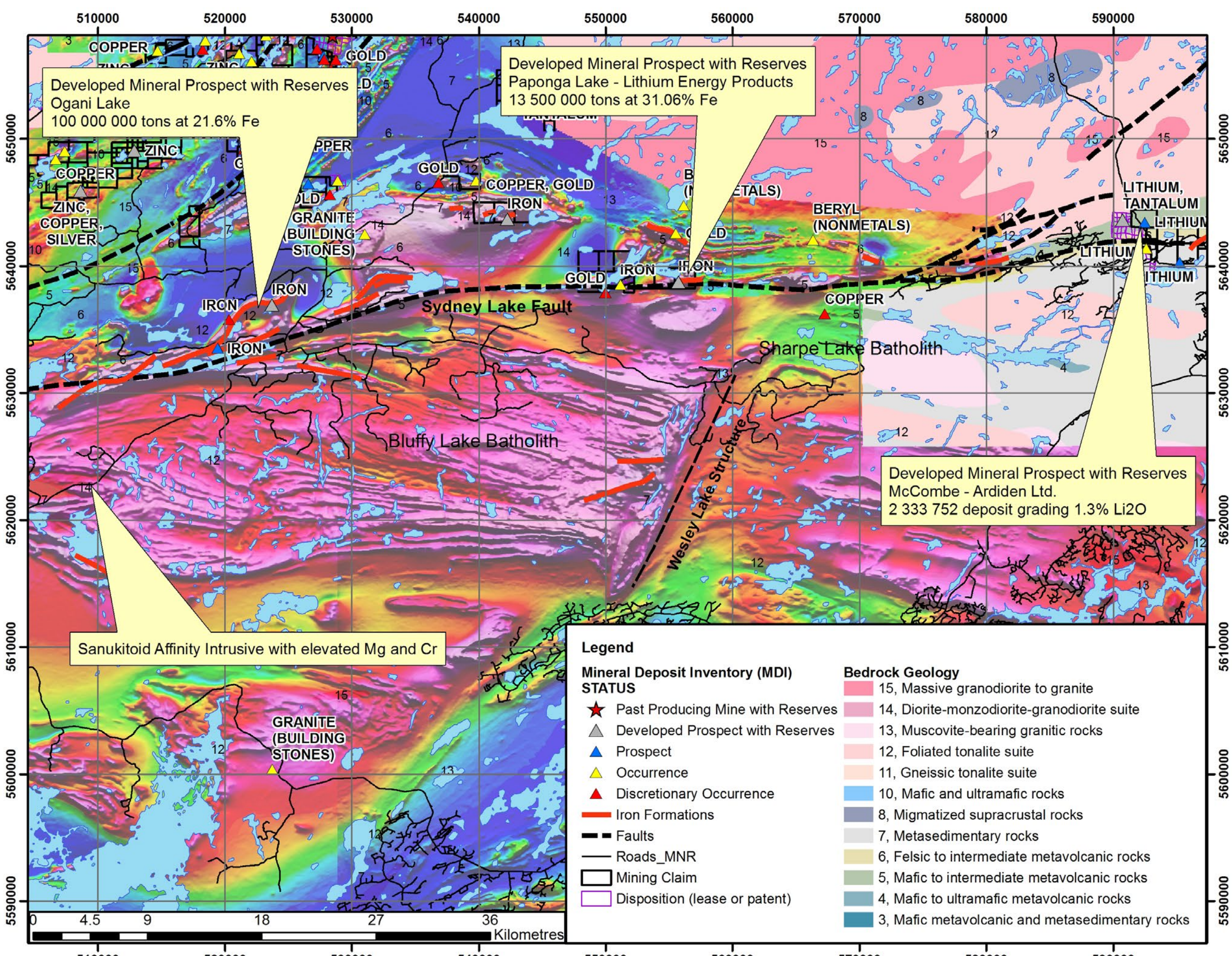

Figure 2. Aeromagnetic survey, locations of mineral occurrences and claim boundaries along the Uchi–English River Subprovince boundary. (Claim information current to October 1, 2017; aeromagnetic survey *from* Ontario Geological Survey 1991, 2017a, 2017b); UTM co-ordinates in NAD83, Zone 15.)

Mineral Potential, Uchi–English River Subprovince Boundary

REFERENCES

Barlow, R.B., Gupta, V.K. and Wadge, D.R. 1976. Bouguer gravity map of the Birch–Uchi–Confederation Lakes area, District of Kenora (Patricia Portion); Ontario Division of Mines, Preliminary Map P.1186, Geophysical Series, scale 1:126 720.

Beakhouse, G.P. 2007. Structurally controlled, magmatic hydrothermal model for Archean lode gold deposits: A working hypothesis; Ontario Geological Survey, Open File Report 6193, 133p.

Beausoleil, C., Fluery, D., Fortin, A., Brisson, T. and Joncas, L. 2014. Éléonore gold project Quebec, Canada, NI 43-101 Technical Report; Goldcorp Inc., filed March 28, 2014 with SEDAR®, see SEDAR Home Page , 261p.

Breaks, F.W., Bond, W.D., Desnoyers, D.W., Stone, D. and Harris, N. 1976. Operation Kenora–Ear Falls, Bruce–Bluffy lake sheet, District of Kenora; Ontario Division of Mines, Preliminary Map P.1199, scale 1:63 360.

Breaks, F.W., Selway, J.B. and Tindle, A.G. 2001. Fertile peraluminous granites and related rare-element pegmatite mineralization, Superior Province, northwest and northeast Ontario; *in* Summary of Field Work and Other Activities, 2001, Ontario Geological Survey, Open File Report 6070, p.39-1 to 39-39.

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

Lichtblau, A., Hinz, P., Ravnaas, C., Storey, C.C., Kosloski, L., Raoul, A. and Gula, R. 2005 Report of Activities 2004, Resident Geologist Program, Red Lake Regional Resident Geologist Report: Red Lake and Kenora Districts; Ontario Geological Survey, Open File Report 6146, p.37.

Lichtblau, A. and Ravnaas, C. 2017. Recommendations for exploration 2016–2017; Northern Development and Mines, Ontario Geological Survey, Resident Geologist Program, p.33-36.

Lichtblau, A.F., Ravnaas, C., Storey, C.C., Debicki, R.L., Lockwood, H.C., Tuomi, R.D., Zurevinski, S.E., Moses, P. and Bongfeldt, J. 2013. Report of Activities 2012, Resident Geologist Program, Red Lake Regional Geologist Report: Red Lake and Kenora Districts; Ontario Geological Survey, Open File Report 6283, p.51-52.

Mulligan, R. 1965. Geology of Canadian lithium deposits; Geological Survey of Canada, Economic Geology Report no.21, p.64-65

Ontario Geological Survey 1991. Airborne electromagnetic and total intensity magnetic survey, Birch–Uchi–Confederation Lake area; Ontario Geological Survey, Maps 81 655 to 81 660 and 81 666 to 81 669, scale 1:20 000.

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

——— 2017a. Airborne magnetic gradiometer and gamma-ray spectrometric surveys, colour-filled contours of residual magnetic field, Separation Lake area; Ontario Geological Survey, Map 82 841, scale 1:50 000.

——— 2017b. Airborne magnetic gradiometer and gamma-ray spectrometric surveys, ternary radioelement image, Lac Seul east area; Ontario Geological Survey, Map 82 918, scale 1:50 000.

——— 2017c. Mineral Deposit Inventory; Ontario Geological Survey, Mineral Deposit Inventory, online database
.

Shklanka, R. 1968. Iron deposits of Ontario; Ontario Geological Survey, Mineral Resources Circular 11, 489p.

Storey, C.C., Hinz, P., Gosselin, S.DM., Blackburn, C.C. and Kosloski, L. 2000. Report of Activities 1999, Resident Geologist Program, Red Lake Regional Resident Geologist Report: Red Lake and Kenora Districts, Ontario Geological Survey, Open File Report 6003, 66p.

Zeng, F. and Calvert, A.J. 2006. Imaging the upper part of the Red Lake greenstone belt, northwestern Ontario, with 3-D traveltime tomography; *in* The Western Superior Province Lithoprobe and NATMAP transects, Canadian Journal of Earth Sciences, v.43, no.7, p.849-863.

HIGHLIGHTS

- **Increased lithium consumption drives up lithium-bearing rare metal pegmatite exploration activity in Ontario.**
- **Substantial strike extent of rare metal occurrences open for staking, anchored by ~8 Mt lithium resource currently being developed.**

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Rare Metal-Bearing Pegmatites Along the Bear Head Fault

Lithium carbonate prices more than doubled in price between 2015 and the end of 2017, from approximately US$8000/t to approximately US$17,750/t (price information *from* www.snl.com *under* Commodity Profile | Lithium [accessed October 25, 2017]), driven by strong demand for lithium-ion batteries in portable consumer electronics, battery electric vehicles and hybrid electric vehicles (Cockburn 2017). As a consequence, exploration for lithium-bearing rare metal pegmatites in Ontario has seen a marked increase (Stephen Jessome, Statistics Analyst, Mineral Sector Analysis and Diamond Unit, Ministry of Northern Development and Mines, personal communication 2017).

A 140 km-long linear zone of peraluminous granite bodies was delineated by Stone (1998) along the Bear Head fault, between Favourable Lake and McDowell Lake. Peraluminous granite and pegmatitic granite represent common parent magmas of rare metal mineralization (Breaks, Tindle and Smith 1998). They may occur in areas proximal to subprovince boundaries, intruding adjacent metasedimentary and metavolcanic rocks. The Bearhead fault lies between the Sachigo Subprovince to the north and the Berens River Subprovince to the south (Figure 1).

Five rare metal mineral occurrences are known from within the zone. The Pakeagama Lake lithium-cesium-tantalum occurrence (MDI53C11SW00003: Ontario Geological Survey 2017) is the most advanced in terms of development. Breaks, Tindle and Smith (1998) stated the Pakeagama pegmatite "represents the second largest complex-type, petalite subtype pegmatite in Ontario, being only surpassed by the Big Whopper pegmatite in the Separation Lake area". The current Canadian National Instrument 43-101-compliant mineral resource estimate shows a Measured and Indicated resource of 7.89 million tonnes of 1.73% lithium oxide equivalent (www.frontierlithium.com *under* Projects [accessed October 25, 2017]).

The other 4 known occurrences lie within 65 km northwest of the Pakeagama Lake deposit and are open for staking (*see* Figure 1).

- MDI53C13SE00089 — Bearhead Lake holmquistite occurrence
- MDI53C12NE00012 — Mattless Lake zinc-beryllium-bismuth-molybdenum occurrence; 0.72% Zn, 0.1% Bi, 0.04% Mo, 0.01% Be (Ayres 1970)
- MDI53C12NE00014 — Pennock Lake holmquistite occurrence
- MDI53C12NE00013 — Pennock Lake spodumene occurrence; 0.52% Li (Ayres 1972)

Follow-up exploration is highly recommended in the immediate vicinity of the known occurrences and in the area underlain by fertile granites in the Favourable Lake area, northwest of the documented occurrences. Fertile granites southeast of the Pakeagama Lake deposit may extend along the trace of the Bear Head fault approximately 75 km toward McDowell Lake. This area is also open for staking.

Rare Metal-Bearing Pegmatites Along the Bear Head Fault

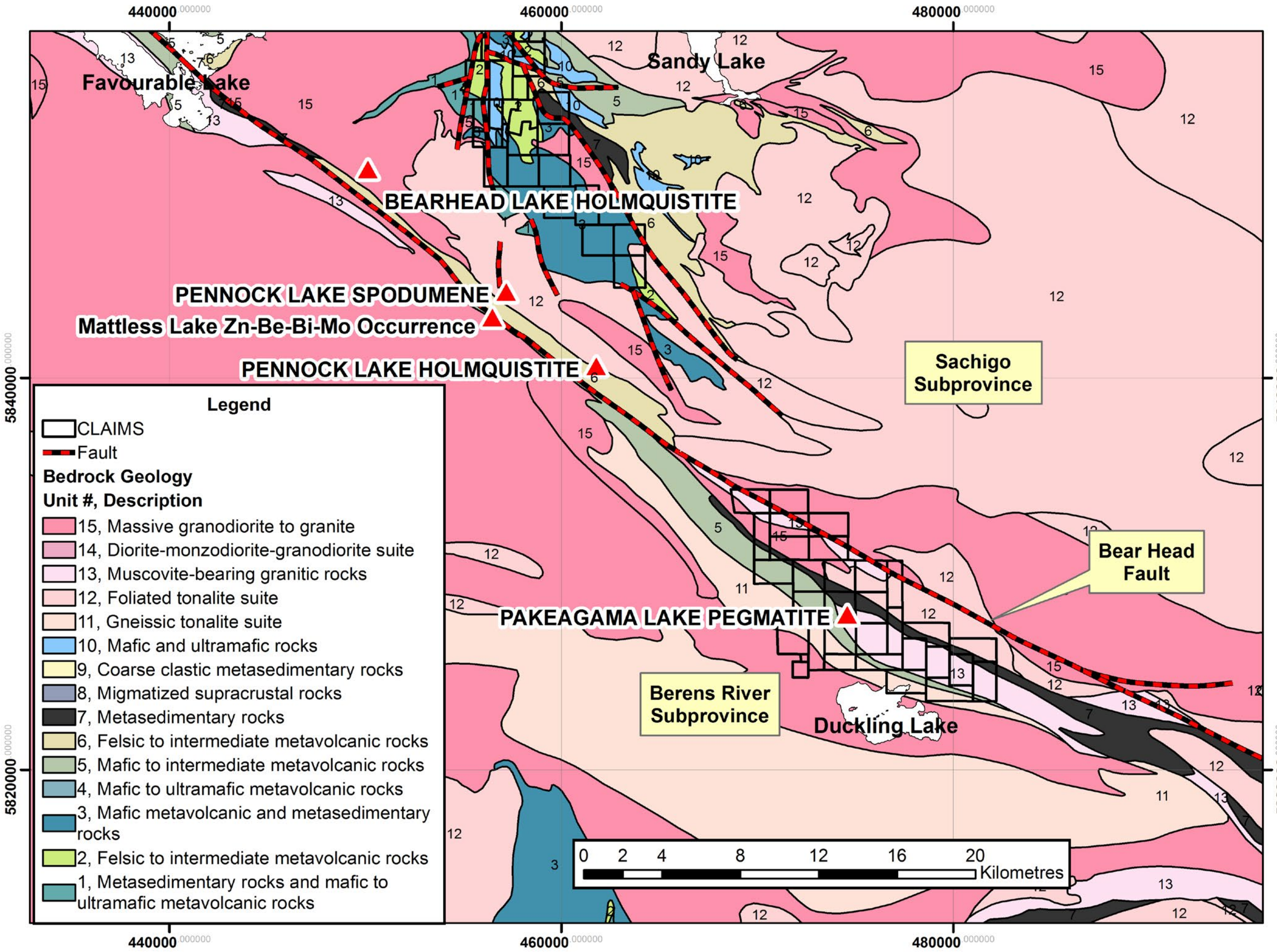

Figure 1. Bedrock geology, locations of rare metal occurrences and claim fabric along the Sachigo–Berens River Subprovince boundary. (Claim information current to October 1, 2017; bedrock geology *from* Ontario Geological Survey 2011; Universal Transverse Mercator (UTM) co-ordinates in North American Datum 1983 (NAD83), Zone 15.)

REFERENCES

Ayres, L.D. 1970. Setting Net Lake area; Ontario Department of Mines, Preliminary Map P.538 (revised), scale 1:15 840.

——— 1972. Setting Net and Northwind lakes area; *in* Summary of Field Work—1972, Geological Branch, Ontario Division of Mines, Miscellaneous Paper 53, p.6-13.

Breaks, F.W., Tindle, A.G. and Smith, S.R. 1998. Rare-metal mineralization associated with the Berens River–Sachigo Subprovince boundary, northwestern Ontario: Discovery of a new zone of complex-type, petalite subtype pegmatite and implications for future exploration; *in* Summary of Field Work and Other Activities, 1998, Ontario Geological Survey, Miscellaneous Paper 169, p.168-182.

Cockburn, C. 2017, Electric-vehicle sales drive up lithium demand; The Globe and Mail, www.theglobeandmail.com/report-on-business/electric-vehicle-sales-drive-up-lithium-demand/article36211287/ [accessed October 25, 2017].

Rare Metal-Bearing Pegmatites Along the Bear Head Fault

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

——— 2017. Mineral Deposit Inventory; Ontario Geological Survey, Mineral Deposit Inventory (October 2017 update), online database.

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

Notes

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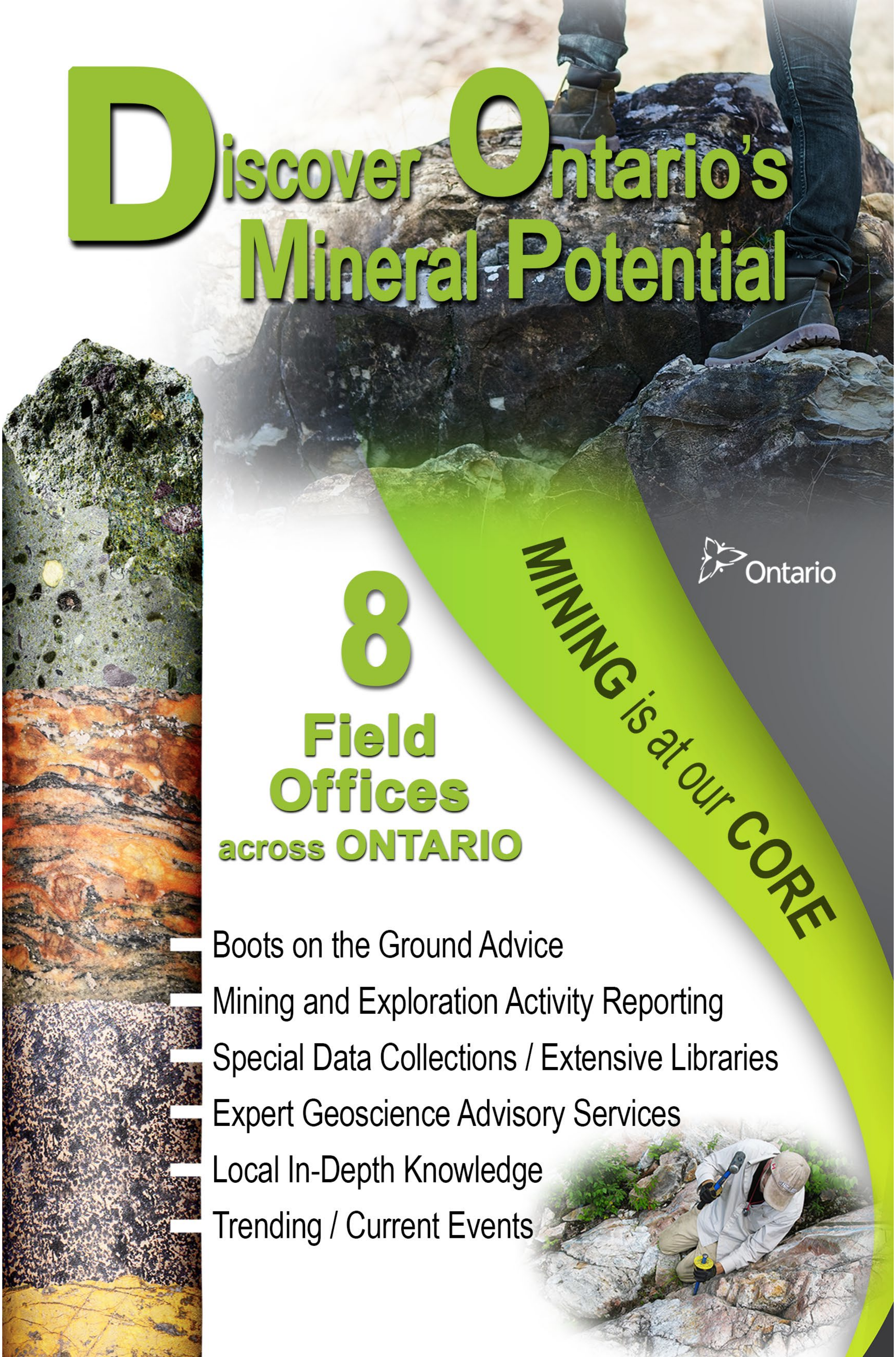
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