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Scoping study for the hydrothermal iron-oxide copper-gold (IOCG) deposit type in Manitoba: summary of regional investigations

By
A.H. Mumin and J.A. Perrin

Manitoba

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Cover photo: (Top) High-grade hydrothermal rare earth element (REE) veins, comprising allanite, britholite, apatite, pyroxene, plagioclase, fluorite, calcite and titanite, invading syenite country rock, Eden Lake, NTS 64C (Granville Lake). **(Bottom)** Late structural breccia rich in hydrothermal sulphides, Notigi iron-sulphide copper-graphite occurrence, NTS 63O (Nelson House). Field of view approximately 7 m.

ABSTRACT

A regional scoping study to investigate the potential for hydrothermal iron-oxide copper-gold (IOCG) and polymetallic styles of mineralization in Manitoba was carried out between 2002 and 2004. The study involved an area of approximately 192 000 km^2 that covers most of the Trans-Hudson Orogen of northern Manitoba. Regional-scale geological compilations, magnetic surveys, equivalent potassium (eK), thorium (eTh) and uranium (eU) radiometric data, and available literature were used to identify potential IOCG systems for follow-up field investigations. A total of 142 target sites are identified and prioritized; however, only 13 of these sites have been examined in the field to date.

Field reconnaissance was also carried out over the south-central Trans-Hudson Orogen, with recognition of igneous-hydrothermal features not identified in the regional compilations. Reconnaissance and detailed fieldwork resulted in 1) discovery of a rare metal–enriched carbonatite complex at Eden Lake; 2) recognition of a widespread and unique style of igneous-hydrothermal mineralization, referred to here as iron-sulphide copper-graphite (ISCG); and 3) various other indications of possible IOCG or other igneous-hydrothermal–associated systems. This study demonstrates that various geotectonic terranes are prospective for several styles of IOCG and related mineralization, and helps provide a framework within which exploration can be carried out in the highly metamorphosed Trans-Hudson Orogen.

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[1] Available online to download free of charge at www2.gov.mb.ca/itm-cat/freedownloads.htm, or on request from minesinfo@gov.mb.ca or Mineral Resources Library, Manitoba Industry, Economic Development and Mines, 360–1395 Ellice Avenue, Winnipeg, MB R3G 3P2, Canada

Introduction

A distinct family of magmatic-associated hydrothermal vein, breccia and/or replacement deposits, characterized by abundant Fe-oxide and enrichment in Fe-Cu-Au±U, rare earth elements (REE), Co, Bi or Ag has only been recognized within the last two decades. The first deposit to be recognized in this classification is the 3.81 billion tonne Olympic Dam Cu-Au-Ag-U deposit in Australia. Other major deposits of the iron-oxide copper-gold (IOCG) type occur in Australia, Sweden, China, Chile and Brazil, and they are now recognized in various localities on every continent (Porter, 2000, 2002b). Iron-oxide copper-gold mineralization has been discovered in a wide range of geotectonic settings, including convergent and extensional environments, both modern and ancient. Deposits of this type have become one of the favourite exploration targets in many parts of the world due to their polymetallic nature, high tonnage and gross-value potential. Consequently, there are many current IOCG-related exploration and development projects worldwide.

At the outset of the present study, there were no known examples of IOCG-type deposits in Manitoba, nor had there been any recorded exploration for this type of mineralization. Consequently, this study was undertaken to assess the geological potential of Manitoba to host IOCG (Olympic Dam)-type deposits.

The IOCG scoping study for Manitoba was initiated in 2002. The focus was quickly narrowed to the Paleoproterozoic terranes of the Trans-Hudson Orogen in northwestern Manitoba, a region of approximately 240 000 km^2 of mostly boreal forest, lakes, rivers and swamp with low outcrop exposure and abundant glacial till and clay overburden. In this study, fourteen 1:250 000-scale NTS areas covering approximately 192 000 km^2 were examined, excluding only the most remote areas (Figure 1). Access to the region is limited to a few roads, inland waterways and floatplane. Most of the region has received very little exploration, with the exception of the Flin Flon greenstone belt, the Thompson Nickel Belt and, to a lesser extent, the Lynn Lake area.

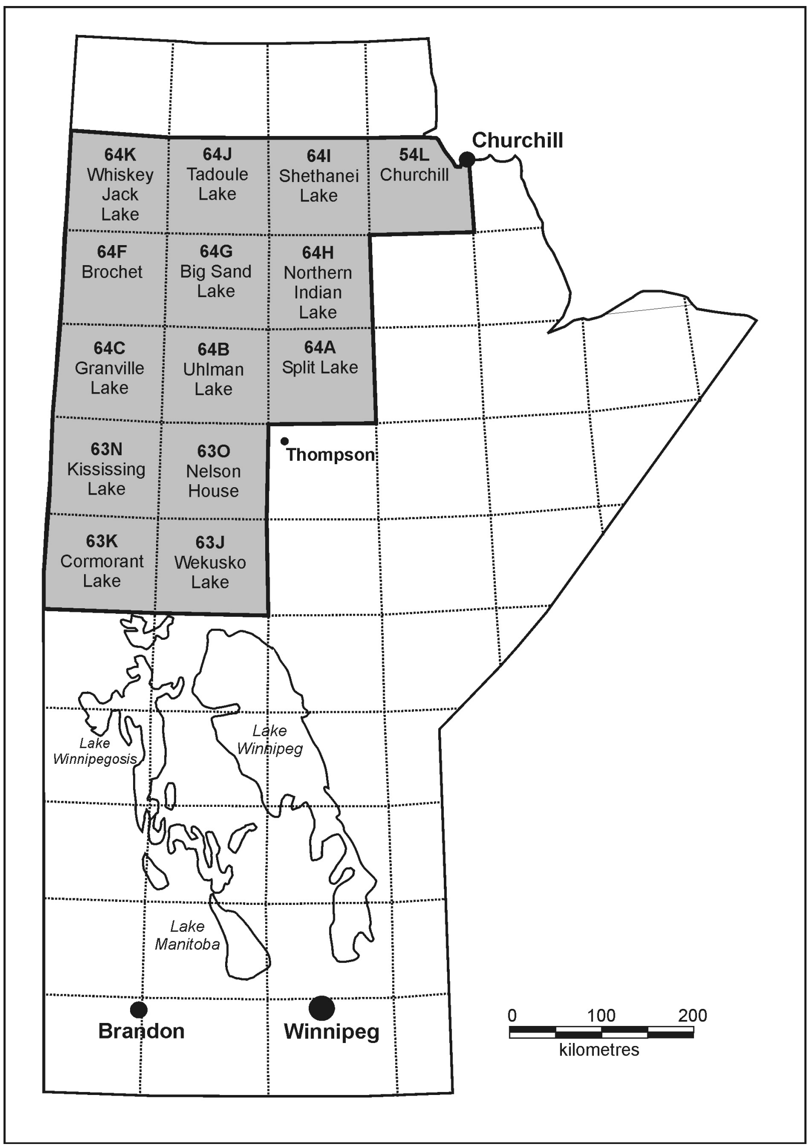

Figure 1: *Location map showing the fourteen 1:250 000-scale NTS areas involved in the iron-oxide copper-gold (IOCG) scoping study.*

Geotectonic setting of the Trans-Hudson Orogen

The Trans-Hudson Orogen (THO) constitutes a major Early to Middle Proterozoic tectonic collage of varied terranes that amalgamated with the Hearne craton in a north-vergent series of collisional events, and eventually sutured to the northwestern Archean Superior Province. Paleoproterozoic granitoid and gneiss terranes, with intervening metasedimentary and metavolcanic belts, predominate in the region. The THO includes early island-arc terranes, accretionary complexes, continental orogenic belts, arc- and continental-rift environments, collisional suture zones and granitoid gneiss belts (Lewry and Stauffer, 1990; Ansdell et al., 1995; Machado et al., 1999; White et al., 2000; Corrigan and Rayner, 2002; Beaumont-Smith and Böhm, 2003; Mumin and Corriveau, 2004). These continental, arc and protocontinental rift and orogenic-belt environments constitute a number of metallogenic terranes favourable of hosting a variety of igneous and hydrothermal styles of mineralization. Deposits of the IOCG type tend to form along these ancient cratonic margins, where melting of deep continental crust to upper mantle produces abundant felsic to intermediate magmas and alkali-rich melts. In spite of the attractive geotectonic setting, the camouflaging effects of high-grade metamorphism, scarcity of outcrop, remoteness and limited access to much of the Trans-Hudson Orogen have left most of it relatively unexplored.

Overview of IOCG deposits

Hydrothermal IOCG deposits are attractive targets for modern exploration and development. They are most abundant in Proterozoic terranes, although Phanerozoic and Archean examples occur in many regions of the world. They are typically polymetallic, with one or more economic metals that may include various combinations of Fe, Cu, Au, Ag, U, Th, F, Co, Bi, W, rare earth elements (REE) and other metals. The size of deposits tends to be large, with the largest in excess of one billion tonnes of ore. A few examples include

- Olympic Dam in Australia (3.81 billion tonnes grading 1.1% Cu, 0.5 g/t Au and 0.4 kg/t U_30_8; WMC Resources, Ltd., 2004);
- Kiruna in Sweden (>2 billion tonnes grading 60% Fe; Carlon, 2000);
- Bayan Obo in China (48–100 million tonnes grading approximately 6% REE oxides, and 1.5 billion tonnes grading 35% Fe; Smith and Chengyu, 2000);
- Candellaria in Chile (470 million tonnes grading 0.95% Cu, 0.22 g/t Au, 3.1 g/t Ag; Marschik et al., 2000); and
- Salobo in Brazil (reserves estimated at 450 million tones grading 1.15% Cu and 0.5 g/t Au; Requia and Fontboté, 2000).

Iron-oxide copper-gold deposits formed along extensional and collisional cratonic margins, both modern and ancient, both incipient and mature, which promoted partial melting of deep continental crust to uppermost mantle rocks and production of magmas of a wide range of compositions. They formed in brittle to brittle-ductile settings, along and at the intersections of major structural lineaments, and display close time-space relationships with distinct alteration styles. The ores are associated with widespread alkali-Fe metasomatism, including multiphase sodic to sodic-calcic and potassic alteration, often associated with alkali-rich felsic intrusions. Enrichment in one or more of PO_4, CO_2 and F is common. Iron is usually magnetite and/or hematite, but can include and is occasionally dominated by Fe silicates, Fe carbonates and/or Fe sulphides. Generally, magnetite forms at deeper levels, as a higher temperature and/or more reduced form of Fe oxide. In contrast, hematite occurs at shallower depths or in peripheral regions of IOCG systems at lower temperature and more oxidizing conditions, although considerable overlap and superposition occur. The source of hydrothermal fluid is orthomagmatic ± secondary circulation of ground water driven by heat of the intrusion. Metals are derived from the intrusion, but can also be leached from the hostrocks.

General information on IOCG deposits can be found in Hitzman et al. (1992), Porter (2000, 2002b) and Corriveau (work in progress, 2005).

Methodology

Three main avenues of investigation were pursued in order to carry out the province-wide IOCG scoping study. Initially, discussions and meetings were held with geologists familiar with the overall geotectonic setting of the province, primarily members of the Manitoba Geological Survey. The provincial geology was reviewed in the context of known features and geotectonic settings for IOCG systems. Prospective regions of Manitoba were identified on the basis of known and suspected tectonic environments, to encompass those areas that were former cratonic margins, either collisional or extensional and either mature or incipient. Attention was also paid to the presence or possibility of late felsic to intermediate volcanoplutonic terranes. Iron-oxide copper-gold deposits are also known to occur along and at the intersections of major structural lineaments, and this is one of the most important exploration guides. Regions of Manitoba that contain known and ancient cratonic margins include both the Archean Superior Province and the Paleoproterozoic Trans-Hudson Orogen (THO). The search was quickly narrowed to the Trans-Hudson Orogen based on the the following criteria:

- Most IOCG deposits occur in Proterozoic terranes.
- Some regions in the THO, particularly Eden Lake, display a number of features characteristic of IOCG systems.
- The THO has an abundance and variety of geotectonic terranes that are potential hosts for igneous-hydrothermal styles of mineralization.

The second phase of the project included examination of available regional geological and geophysical survey data covering the Trans-Hudson Orogen, and identifying and prioritizing target areas for follow-up field investigations. The surveys and techniques used are described below, along with location maps and tables of all selected targets. The selected targets were crudely prioritized on the basis of

- coincidence of several anomalous features,

- intensity of anomalies,
- late felsic to intermediate volcanoplutonic host geology,
- association of major crustal lineaments or geotectonic boundaries, and
- known presence of potential IOCG-associated alteration or mineralization.

Nevertheless, even the subtlest of anomalies detected by the regional surveys could prove to be more important than the obvious ones, so some important target sites may have been easily overlooked during the present study.

Compilation reviews were conducted for each of the fourteen 1:250 000-scale NTS areas. Regional survey data that were available for the Trans-Hudson Orogen and used in this study included

- bedrock geology compilation maps,
- regional aeromagnetic survey maps,
- regional eK radiometric survey data,
- regional eTh radiometric survey data,
- regional eU radiometric survey data,
- regional eU/eTh radiometric ratio maps, and
- regional eK/eTh radiometric ratio maps.

Prior to visiting selected targets in the field, the sites were further investigated using the available geological literature, Manitoba assessment files and, where possible, discussions with persons knowledgeable in the area.

The third phase of the scoping study included field reconnaissance and, in some cases, follow-up field visits to identified target areas for detailed investigations. In addition, nontargeted regional reconnaissance fieldwork was carried out to test for geological features and sites of interest not evident from the review of existing regional data. Due to the abundance, size, complexity and remoteness of most targets, the fieldwork phase of the project will likely require many years to complete. The results of field investigations reported here and in Mumin (2002a, b) and Mumin and Trott (2003) were carried out in 2002, 2003 and 2004.

Regional surveys applied to the search for IOCG deposits

Magnetic surveys

Regional airborne magnetic surveys are available for all of Manitoba, flown at approximately 0.5 mile line spacing and an altitude of 1000 feet. Canadian Aero Services Ltd. carried out the surveys in the early 1960s, and the data are presented on maps at 1:50 000 scale and larger.

The abundance of magnetite ± other Fe-rich minerals in IOCG deposits renders them possible targets for detection by magnetic surveys. In particular, point-source, subtle or strong anomalies in felsic volcanoplutonic terranes are of interest. Since IOCG deposits tend to be intrusion-related point-source hydrothermal features, their associated magnetic anomalies can sometimes be distinguished from linear anomalies associated with iron formations and other stratiform phenomena.

Radiometric surveys

Many IOGC deposits are associated with regional-scale and/or site-specific anomalous U, Th and/or K concentrations. Consequently, they are subject to possible detection by radiometric survey techniques. Further, due to different hydrothermal leaching, transport and concentration characteristics, the radiometric eTh/eK ratio and/or eU/eTh ratio can be used in some cases to distinguish whether high concentrations are due to hydrothermal metasomatism or normal igneous-fractionation processes. The regional data used in the present study, however, may not be sensitive enough or of sufficiently high resolution to be particularly effective for this purpose.

In Manitoba, regional airborne radiometric Th, U and K surveys are available for 13 of the 14 NTS areas examined (no data were available for NTS 64H, Northern Indian Lake). These data are available as 1:250 000- and 1:1 000 000-scale compilation maps published in 1984. The radiometric maps were compiled from airborne gamma-ray spectrometric surveys flown with line spacing of approximately 5 km. The planned survey altitude was 120 m and ground speed was between 190 and 240 km/hr. The surveys were carried out by the Geological Survey of Canada (GSC) or by contractors following GSC specifications.

Bedrock geology

Regional bedrock geology compilation maps are available for all NTS areas in Manitoba. Due to the association of IOCG deposits with late volcanoplutonic terranes, alkali-rich felsic to intermediate rocks and regional structural lineaments and terrane boundaries, the regional geology maps are quite useful in helping to select geophysical anomalies and geological terranes of interest.

Mineral Resources Division assessment files and geoscience databases

These online and library-archived databases include geological, geophysical, geochemical, diamond-drilling, mineralogical and exploration surveys and research reports. Where information was available, it was used to further screen and narrow potential target sites prior to field investigations.

Limitations of the survey techniques used in this study

The geological and geophysical surveys used in this study are regional in scope and provide very low resolution. Consequently, they fail to identify many important features and details that cannot be detected with such a large spatial resolution due to the averaging of effects associated with the data processing. In addition, many types of IOCG deposits do not display the classic features discussed above. Consequently, their presence could be cryptic or they may be altered by high-grade metamorphism and deformation into another form not easily recognized. Northern Manitoba is largely covered by overburden, swamps and bodies of water, and has very little exposed bedrock. Therefore, radiometric signatures are easily masked and are not detected beneath as little as 1 m of overburden or water. Cultural factors may also cause deceptive radiometric anomalies. For example, large isolated exposures of bedrock can result in deceptive radiometric anomalies, simply because the surrounding background readings are depressed by regionally extensive overburden cover.

Aeromagnetic surveys do not detect all pertinent Fe-rich minerals, and thus will not recognize IOCG deposits characterized by high hematite or other nonmagnetic Fe-bearing minerals. Many areas with significant concentrations of moderately magnetic minerals, such as pyrrhotite, remain completely undetected by the present regional magnetic surveys due to the low resolution and sensitivity. Furthermore, many geological features have anomalous magnetic signatures, essentially negating the effectiveness of magnetic data unless used in conjunction with other criteria.

Explanation of the tables of potential IOCG target sites

The full listing of 142 potential IOCG target sites is given in Tables 1 to 14, with corresponding location maps presented in Figures 2 to 15. The pertinent information given in the tables is

- name of the NTS map area;
- target priority, from 1 (highest priority) to 4 (lowest priority);
- identification number of the anomalous site;
- general geographic location;
- immediate hostrock geology;
- approximate magnetic anomaly (in gammas, calculated as high minus background), subdivided into the following four categories:

Weak	< 500 gammas
Moderate	500–2000 gammas
Strong	2000–5000 gammas
Very strong	>5000 gammas

- peak eK anomaly (reported in wt.%);
- peak eTh anomaly (reported in ppm);
- peak eU/eTh ratio anomaly; and
- any pertinent notes.

Only the peak anomaly values of eK, eTh and eU are reported here; consequently, the reader must subtract the background values for a better reading of the actual intensity of the anomalies. Due to the low resolution of the surveys, however, background values show relatively little variation across the region. Average background values range from 0.8 to 1.0 wt.% for eK, 3 to 5 ppm for eTh, and 0.05 to 0.15 for eU/eTh ratios.

Geochemical data

Whole-rock and trace-element geochemical data for 224 samples pertaining to this study are included in Data Repository item 2005002.[1] The data are subdivided according to general location, including the following areas: Eden Lake, IOCG regional, Notigi quarry 1 and 2, Km 54, Suwannee Lake, Cu-quarry, Km 75, Central Granville Complex, Granville Lake, Foot Lake dome, Rat Lake, Wolfcub Lake, Allen Lake, Opachuanau Lake, and South Indian Lake Road quarry.

Maps and tables summarizing the selected targets for the 14 NTS areas examined

Table 1 and Figure 2:	Selected targets for follow-up IOCG investigation, NTS 64K (Whiskey Jack Lake)
Table 2 and Figure 3:	Selected targets for follow-up IOCG investigation, NTS 64J (Tadoule Lake)
Table 3 and Figure 4:	Selected targets for follow-up IOCG investigation, NTS 64I (Shethanei Lake)
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Table 11 and Figure 12:	Selected targets for follow-up IOCG investigation, NTS 63N (Kississing Lake)
Table 12 and Figure 13:	Selected targets for follow-up IOCG investigation, NTS 63O (Nelson House)
Table 13 and Figure 14:	Selected targets for follow-up IOCG investigation, NTS 63K (Cormorant Lake)
Table 14 and Figure 15:	Selected targets for follow-up IOCG investigation, NTS 63J (Wekusko Lake)

[1] MGS Data Repository item 2005002, containing the data or other information sources used to compile this report, is available online to download free of charge at www2.gov.mb.ca/itm-cat/freedownloads.htm, or on request from minesinfo@gov.mb.ca or Mineral Resources Library, Manitoba Industry, Economic Development and Mines, 360–1395 Ellice Avenue, Winnipeg, MB R3G 3P2, Canada.

Table 1: Selected targets for follow-up IOCG investigation, NTS 64K (Whiskey Jack Lake).

ID #	Priority	Location	Surface geology	Mag (gamma)	eK (%)	eTh (ppm)	eU/eTh	Notes
1	3	SE Ducharme Lake	Overburden	Moderate	1.4-1.6	7.0-8	0.1-0.15	
2-Z	3	NE Ducharme Lake	Likely quartz monzonite	Moderate	1.0-1.2	6.0-7.0	0.1-0.15	
3	4	S of Chartrand Lake	Overburden	Moderate	1-1.2	5.0-6.0	0.1-0.15	
4	2	NE Chartrand Lake	Outcrop to NW is mixture of monzo-granite and gneiss	Weak	2.2-2.4	13.0-14.0	0.1-0.15	
5	4	NW Chartrand Lake	Overburden	Moderate	1.0-1.2	11.0-12.0	0.1-0.15	
6-Z	2	NE Cochrane River	Quartz monzonite batholith	Weak	2.0-2.2	12.0-13.0	0.05-0.1	
7-Z	2	E Cochrane River	“	Moderate	2.4-2.3	10.0-11.0	0.05-0.1	
8-Z	1	SE Cochrane River	“	Weak	2.0-2.2	10.0-11.0	0.05-0.1	
9-S	3	NE shore of Lac Brochet	Meta-arkose with nearby monzonite intrusions	Moderate	1.0-1.2	4.0-5.0	0.1-0.15	Mag anomaly surrounded by K highs
10	3	NE Lac Brochet	“	Moderate	1.2-1.4	6.0-7.0	0.05-0.1	Mag anomaly surrounded by K highs
11-S	4	SE Maria Lake	Boundary with monzonite and meta-arkose	Moderate	1.0-1.2	4.0-5.0	0.1-0.15	Mag coincides with K & Th low
12-Z	1	S Sandy Lake	White granite, meta-arkose, quartz monzonite	Weak	3.0-3.2	19.0-20.0	0.1-0.15	
13	3	NE Dean Lake	Straddles contact between metatexite and pink aplite	Weak	1.6-1.8	8.0-9.0	0.1-0.15	Mag coincides with K & Th low
14-S	4	SW shore of Jackfish Lake	Near contact between meta-arkose and pink aplite	Weak	1.4-1.6	8.0-9.0	0.1-0.15	Very low radiometrics centred in lake
15-Z	3	SW shores of Chatwin Lake	Foliated quartz monzonite and meta-arkose	Weak	1.8-2.0	12.0-13.0	0.1-0.15	
16-S	3	NW Rutledge Lake	Meta-arkose and metatexite	Moderate	1.8-2.0	7.0-8.0	0.1-0.15	
17	3	NW Rutledge Lake	Metatexite	Moderate	1.0-1.2	5.0-6.0	0.1-0.15	
18	3	S Ruteidge Lake	Metatexite	Moderate	1.8-2.0	6.0-7.0	0.1-0.15	

Summary of field observations from selected targets in NTS 63O (Nelson House)

Site 1-G: SW Wapisu Lake

The Wapisu anomaly consists of strong, coincident magnetic and radiometric eK, eTh and eU anomalies associated with late felsic intrusions into metasedimentary rocks of the Kisseynew Domain. This region is a good example of the types of associated phenomena that are of interest in this study. Consequently, it is presented here as a case example of how the available regional information can be brought together to identify potential targets for follow-up reconnaissance and detailed scientific investigation and/or exploration. The anomalies are shown superimposed on the regional geology map in Figure 16. Field investigation identified the source of the anomalies as potassic (altered?) porphyritic granite to granodiorite. Potassic felsic breccia units are present locally (Figure 17); however, due to metamorphism and alteration, their origin is not obvious and remains undetermined. Both primary

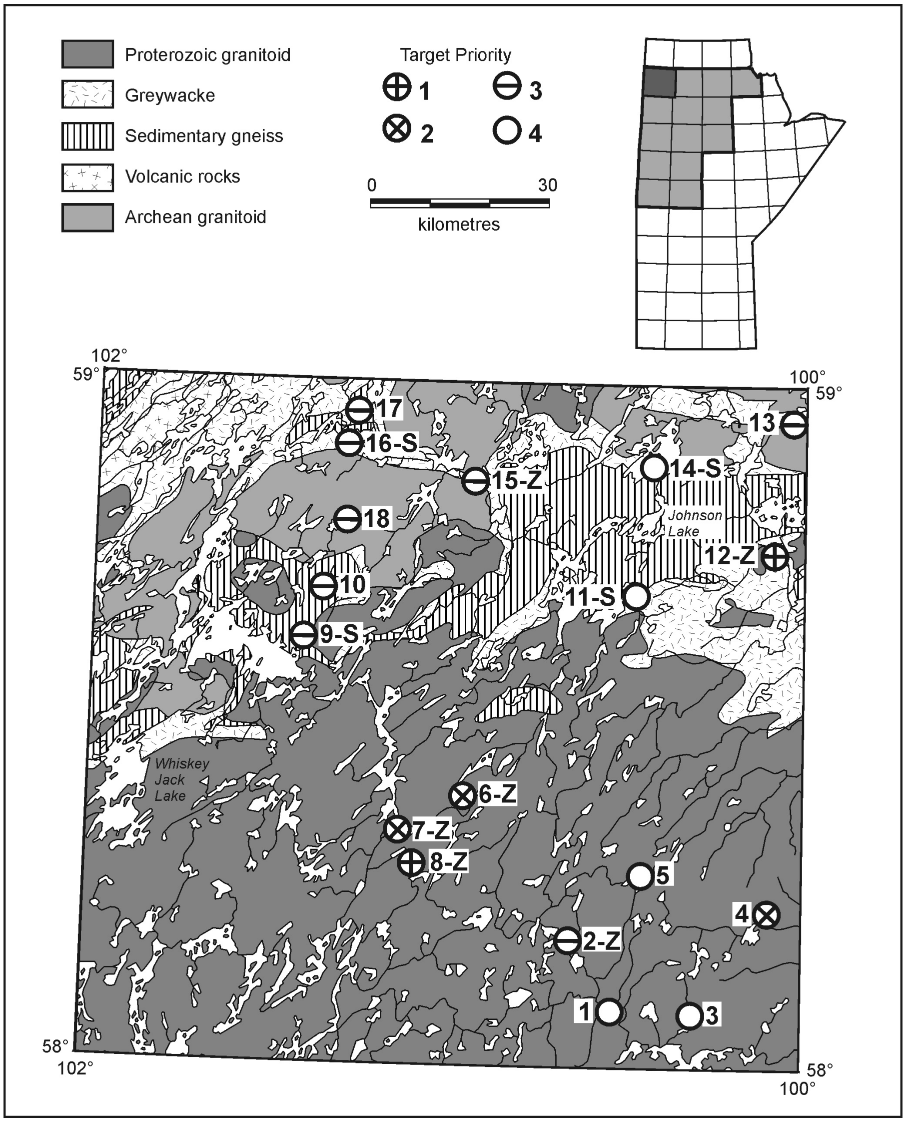

Figure 2: *Selected targets for follow-up IOCG investigation, NTS 64K (Whiskey Jack Lake).*

tectonic or pyroclastic origins are possible. The source of the magnetic high associated with the Wapisu anomaly is, at least in part, lensoid bodies of magnetite-bearing rocks intermittently (Figure 18) dispersed within the potassic felsic rocks. The origin of these magnetite-bearing rocks is also presently undetermined, but metamorphic and/or hydrothermal origins are probable.

Another important feature of the Wapisu anomaly is the further coincidence of structural lineaments (Figure 16). Some structures extend north from the anomaly directly into a known mineralized structure that hosts the Notigi ISCG mineralization described by Mumin and Trott (2003) and later in this report. The Notigi occurrence is a late structural-breccia zone that hosts abundant pyrrhotite-quartz-graphite±minor chalcopyrite mineralization (Figure 19). A recent finding at Notigi is the presence of carbonate-rich material that appears to be olivine carbonatite, intimately associated with a pyroxenite intrusion and the sulphide mineralization. Other, smaller, structurally hosted ISCG occurrences are also present in the general area. Mumin and Trott (2003) suggested that the ISCG mineralization is associated with late intrusions into the Kisseynew metasedimentary rocks (see also following discussions). The possible direct structural link between the Wapisu Lake anomaly and the Notigi mineralization shown here, and the presence of probable carbonatite, present a compelling reason why these potentially related features should be systematically explored for IOCG or other igneous-hydrothermal mineralization.

Site 3: Odei River west

The Odei River west anomaly occurs in Kisseynew metasedimentary rocks near Highway 391. It is marked by coincident magnetic and radiometric eK, eTh and eU anomalies. Although the source of the anomalies has not been identified in the field, it remains of interest due to its proximity to known ISCG-type mineralization, such as those described by Mumin and Trott (2003) and in following discussions. The ISCG occurrences are thought to be hydrothermally deposited and structurally hosted mineralization associated with felsic

Table 2: Selected targets for follow-up IOCG investigation, NTS 64J (Tadoule Lake).

ID #	Priority	Location	Surface geology	Mag (gamma)	eK (%)	eTh (ppm)	eU/eTh	Notes
1	3	SW Kinsman Lake	Overburden	Strong	1.2-1.4	5.0-6.0	0.1-0.15	Large monzonite batholith
2	1	N Samson Lake	Overburden	Weak	2.0-2.2	7.0-8.0	0.1-0.15	Radiometric anomalies just north of mag
3	3	W South Seal River	Overburden	Moderate	0.8-1.0	6.0-7.0	0.1-0.15	
4	3	E South Seal River	Overburden	Moderate	0.8-1.0	5.0-6.0	0.1-0.15	
5-Z?	1	SW Sprott Lake	Quartz monzonite	Moderate	1.6-1.8	8.0-9.0	0.1-0.15	Mag in centre of K low
6-Z	2	W Bain Lake	Quartz monzonite and (magnetite) granite gneiss	Weak	2.6-2.8	11.0-12.0	0.1-0.15	Mag mimics shape of metamorphic remnant
7	4	E Morand Lake	Overburden	Moderate	0.8-1.0	4.0-5.0	0.15	

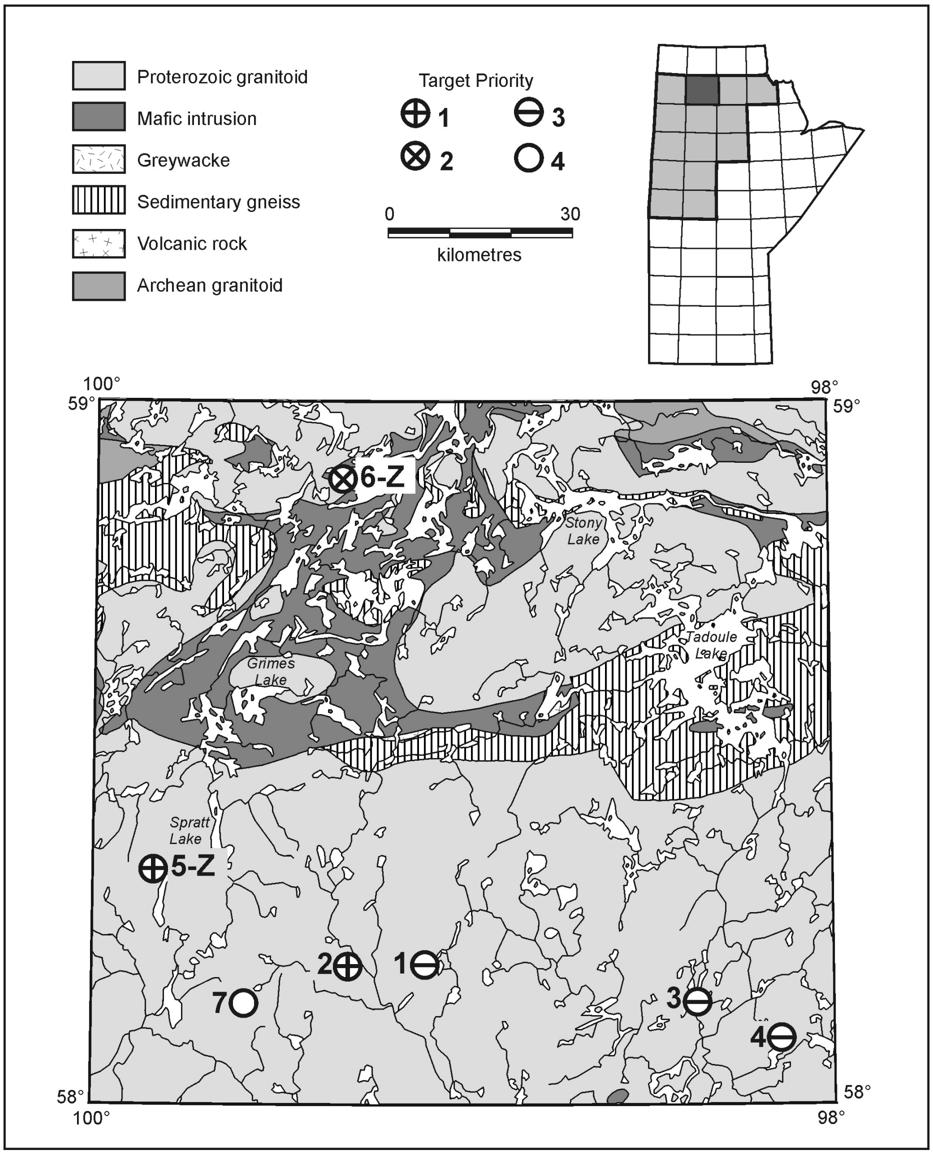

Figure 3: Selected targets for follow-up IOCG investigation, NTS 64J (Tadoule Lake).

Table 3: Selected targets for follow-up IOCG investigation, NTS 64I (Shethanei Lake).

ID #	Priority	Location	Surface geology	Mag (gamma)	eK (%)	eTh (ppm)	eU/eTh	**Notes**
1	3	S Shethanei Lake	Overburden	negative	2.2-2.4	11.0-12.0	0.15-0.20	
2	3	96°45'W, Seal River	Quartz porphyry and quartzite	none	2.4-2.6	14.0-15.0	0.2-0.25	
3	2	58°50'N, 96°03'W	Overburden (nearby volcanics)	weak	1.8-2.0	10.0-11.0	0.2-0.25	
4-Z	1	58°45'N, 96°04'W	Quartz monzonite, pink fluorite-bearing monzonite & volcanics (andesite, basalt, rhyolite)	weak	2.4-2.6	11.0-12.0	0.15-0.20	River & esker run between two K/Th highs
5-Z	3	NW Lovat Lake	Quartz monzonite intruding quartzite	weak	1.8-2.0	7.0-8.0	0.15-0.2	
6-V	3	E Wither Lake	Volcanics (intermediate tuff) & quartz monzonite	weak	2.2-2.4	13.0-14.0	0.2-0.25	K/Th high to north of mag, to south of mag is eU/eTh
7	4	W Quinn Lake	Overburden	weak	1.8-2.0	8.0-9.0	0.15-0.20	
8	1	NE Ashley Lake	Overburden	moderate	1.6-1.8	7.0-8.0	0.15-0.20	Mag SW of K/Th
9	3	NE Ashley Lake	Overburden	weak	1.4-1.6	6.0-7.0	0.1-0.15	Mag SE of radiometrics
10	3	E North Knife Lake	Overburden	moderate	1.2-1.4	6.0-7.0	0.15-0.20	

intrusions. As with Notigi, the proximity of regional anomalous features and the ISCG mineralization makes this area a target for further exploration.

Summary of field observations from selected targets in NTS 64B (Uhlman Lake)

Site 1-G: Northwest and northeast South Bay

This region is characterized by granitoid rocks that intrude syntectonic porphyritic granodiorite plutons with remnants of metasedimentary rocks. The area of interest has a weak magnetic feature and a regionally extensive series of radiometric eK, eTh and eU anomalies that extends for many kilometres on both sides of the South Bay–South Indian Lake channel. Porphyritic granodiorite intrusions locally contain minor hematite or magnetite. Pinkish granite bodies intrude the granodiorite and metasedimentary rocks at various locations. Some potassic granite containing clots and veins of disseminated magnetite is exposed along the South Indian Lake Road (Figure 20). Glacial boulders and cobbles of potassic felsic igneous rocks with moderate amounts of earthy to specular hematite are found in a number of localities in this region, and potassic-altered diatreme-like boulders were identified in 2004. The potassic diatreme-like boulders comprise angular shards and xenocrysts resembling explosion breccia, and contain altered rounded xenoliths with clay alteration of feldspars only internal to the xenolith. Both xenocrysts and xenoliths are consistent with derivation from the megacrystic granitoid of the South Bay region. The diatreme-like material is intensely altered, with 10–11 wt.% K_2O, and is surface weathered (appears to be paleoweathering), but does not show any evidence of the regional high-grade metamorphism. The source of the boulders remains unknown, however, and their possible association with potential IOCG type systems remains speculative. The vast majority of this region remains completely uninvestigated and further work is recommended.

Site 8-G/T: Northwest Cousins Lake

This anomalous area occurs in regionally extensive megacrystic granite. It consists of two separate sites of adjacent eK and magnetic anomalies (~5 km apart). A very strongly magnetic feature northwest of Cousins Lake correlates with a previously unknown magnetite-rich gabbro intruding the granite. Only a very small portion of this feature was accessible for examination, but this is apparently another good example of the young mafic igneous rocks that intrude various parts of the Trans-Hudson Orogen (c.f. Mumin and Corriveau, 2004). About 5 km west of the gabbro, a strong point-source radiometric eK anomaly correlates with a well-exposed, medium- to coarse-grained, unmetamorphosed, monotonous and featureless granite dome (Figure 21). It appears that both this granite and the previously mentioned gabbro are late collisional intrusions into arc-plutonic terrane that separates the Chipewyan Batholithic Complex from the Kisseynew Domain (cf. White et al., 2000). The strong radiometric eK anomaly associated with this site is of unknown origin, but may be an artifact of a 'normal' or moderately potassium-enriched granite lying exposed within a region of extensive overburden and minimal outcrop. The overburden has the potential to depress the surrounding background radiometric signature, thus generating a spurious anomaly, or accentuating a moderate anomaly, over exposed outcrop.

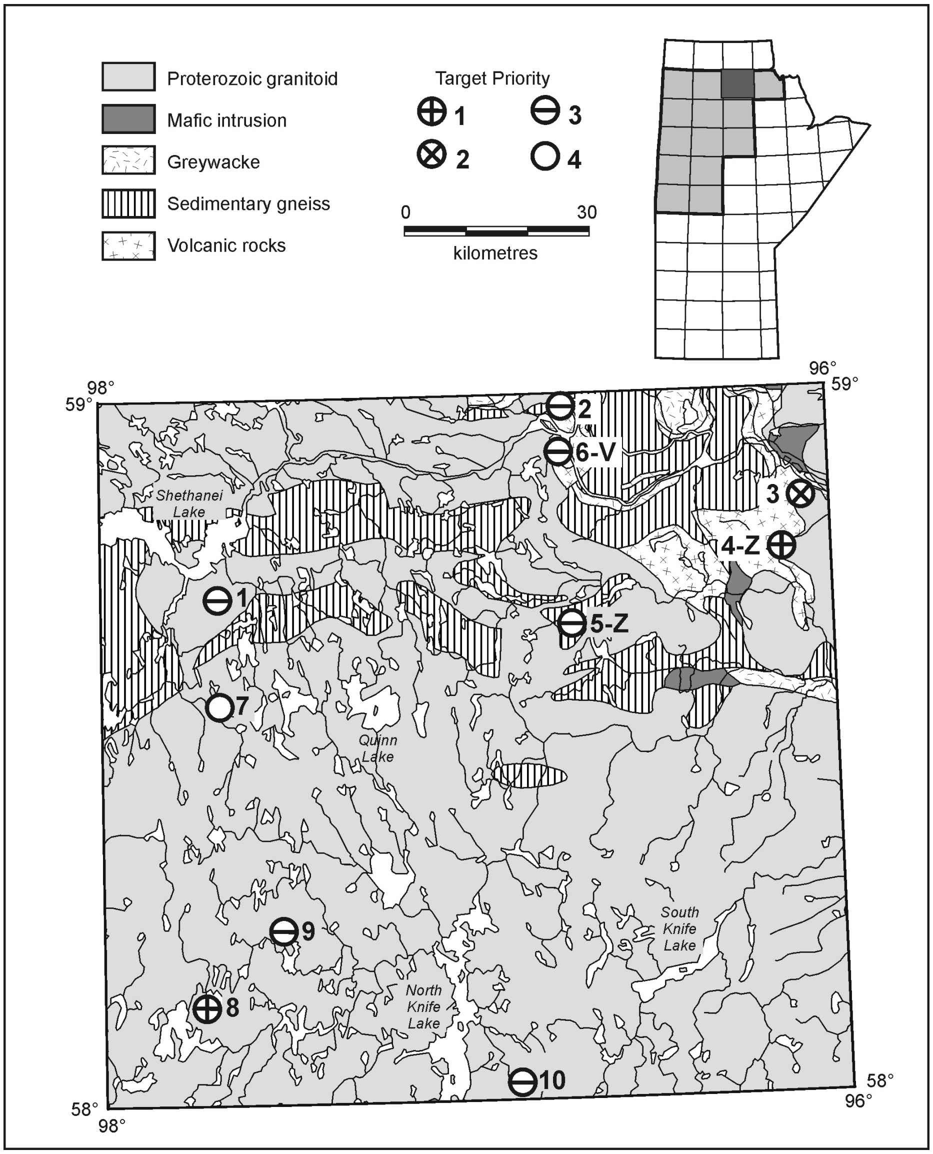

Figure 4: *Selected targets for follow-up IOCG investigation, NTS 64I (Shethanei Lake).*

Site 13-D: Black Trout diorite and magnetite granite, Granville, Suwannee and Rat lakes

The Black Trout diorite (BtD) is characterized by high magnetite and apatite concentrations, the dominant minerals in some Kiruna-type IOCG Fe±Cu ores (Carlon, 2000) and common constituents of many other IOCG deposits. Consequently, a regional reconnaissance of the Black Trout diorite and associated rocks was of relevance to the present study. The BtD occurs as a series of dike-like intrusions that are exposed intermittently for more than 100 km through a portion of the northern margin of the Kisseynew Domain. Where examined in the Suwannee and Rat Lake areas, it resembles normal intermediate foliated diorite, except for an abundance of magnetite (up to 20% in some samples). One location near a magnetic feature in northern Suwannee Lake has exposures of BtD with veins of coarse-grained magnetite and abundant apatite (Figure 22). The main areas that are associated with magnetic anomalies and correlate with projections of the BtD, however, were not exposed to examination. Any large body of this unit remains of interest.

Calcsilicate rocks are exposed along the shoreline and on islands on the south side of Suwannee Lake. On one southern island, corrugated marble-calcsilicate rock is interlayered with sulphidic metasediment. The west side of the same island exposes pink-orange to deep hematitic red, altered granite-monzonite with up to 15% magnetite±hematite disseminations and veins (Figure 23). The small exposure of this material would resemble granite-hosted IOCG mineralization if the Fe-oxide veining were several times more abundant and extensive.

Sites 9-G and 14-G: Foot Lake Complex, west Opachuanau region

A regionally extensive zone of high radiometric eK, eTh and eU extends eastward from Kwaskwaypichikun Bay on Eden Lake for approximately 25 km toward Opachuanau Lake. The area is regionally underlain by porphyritic granodiorite, with a large core region of biotite granite. An area approximately 7 km

Table 4: Selected targets for follow-up IOCG investigation, NTS 54L (Churchill).

ID #	Priority	Location	Surface geology	Mag (gamma)	eK (%)	eTh (ppm)	eU/eTh	Notes
1-Z	2	S Seal River	Quartz monzonite	Weak	2.4-2.6	10.0-11.0	0.2-0.25	
2-G	3	SE Seal River	Granite (pegmatite, +/- fluorite), near contact with quartzite	None	2.0-2.2	12.0-13.0	0.2-0.25	
3	4	E Seal River	Overburden	None	2.4-2.6	15.0-16.0	0.2-0.25	Fault to west of radiometrics

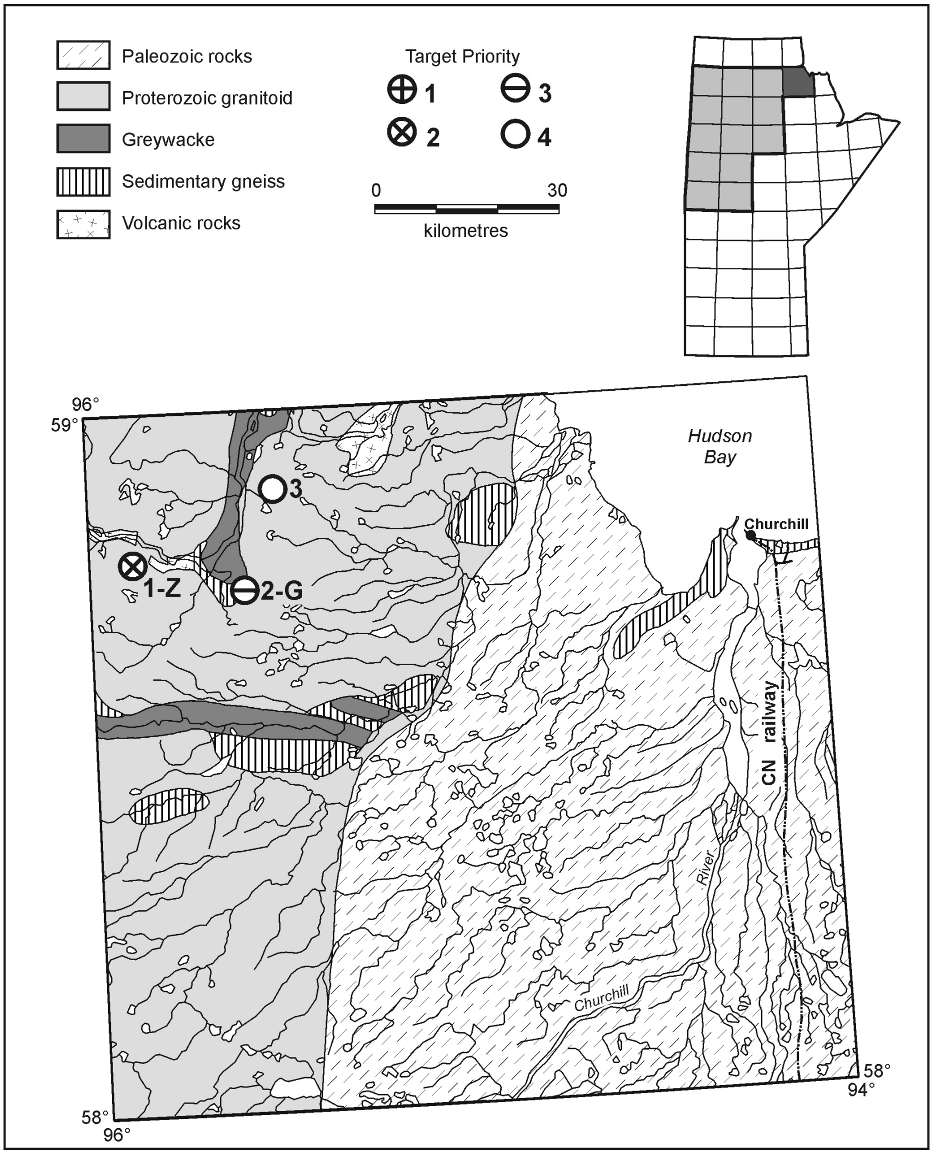

Figure 5: Selected targets for follow-up IOCG investigation, NTS 54L (Churchill).

east of Eden Lake was subjected to reconnaissance examination in the present study. The southern part of the examined area encompasses a series of prominent rocky hills underlain by massive, amoeboid, two-feldspar pegmatite bodies that intrude the biotite granite. The geology of greatest interest, however, is exposed in several domal outcrops west of Foot Lake (referred to as the 'Foot Lake Complex'). The Foot Lake complex comprises young granite bodies intruding a regional biotite monzogranite. Where examined, abundant pyroxene-bearing syenite, monzonite, quartz monzonite and aplite dikes and stocks form a crude but large-scale igneous stockwork that intrudes the young granite. Also, wispy pyroxene veining, pocked syenite (Figure 24) and other forms of hydrothermal alteration are evident locally throughout the complex as veins and patchy zones. The igneous complex is well preserved and not affected by the regional high-grade metamorphism and

Table 5: Selected targets for follow-up IOCG investigation, NTS 64F (Brochet).

ID #	Priority	Location	Surface geology	Mag (gamma)	eK (%)	eTh (ppm)	eU/eTh	Notes
1-G	1	NW tip of Le Clair Lake	Granitic intrusion in gneissic granodiorite	Moderate	1.8-2.0	9.0-10.0	0.1-0.15	Mag anomaly mimics granite intrusion and reads high in magnetite-bearing granodiorite
2-N	2	W Wells Lake	Quartzofeldspathic migmatite in contact with megacrystic monzogranite & magnetic diorite	Moderate	1.8-2.0	6.0-7.0	0.1-0.15	Fault along western edge of anomaly
3-G	2	W Carlson Lake	Megacrystic monzo-granite & gneissic magnetite granodiorite	Moderate	2.4-2.6	8.0-9.0	<0.10	Mag high in monzo-granite
4-G	3	NW Kustra Lake	Granite & megacrystic granite	Moderate	2.0-2.2	10.0-11.0	<0.1	Mag SW of K/Th
5-G	3	E Carlson Lake	Megacrystic granite & granodiorite	Weak	2.4-2.6	4.0-5.0	0.1-0.15	K high in granite, low in adjacent granodiorite
6-T/G	4	E Eyrie Lake	Tonalite, metawacke, granite	Weak	2.0-2.2	8.0-9.0	0.1-0.15	K low in granite separated from K high in tonalite by fault

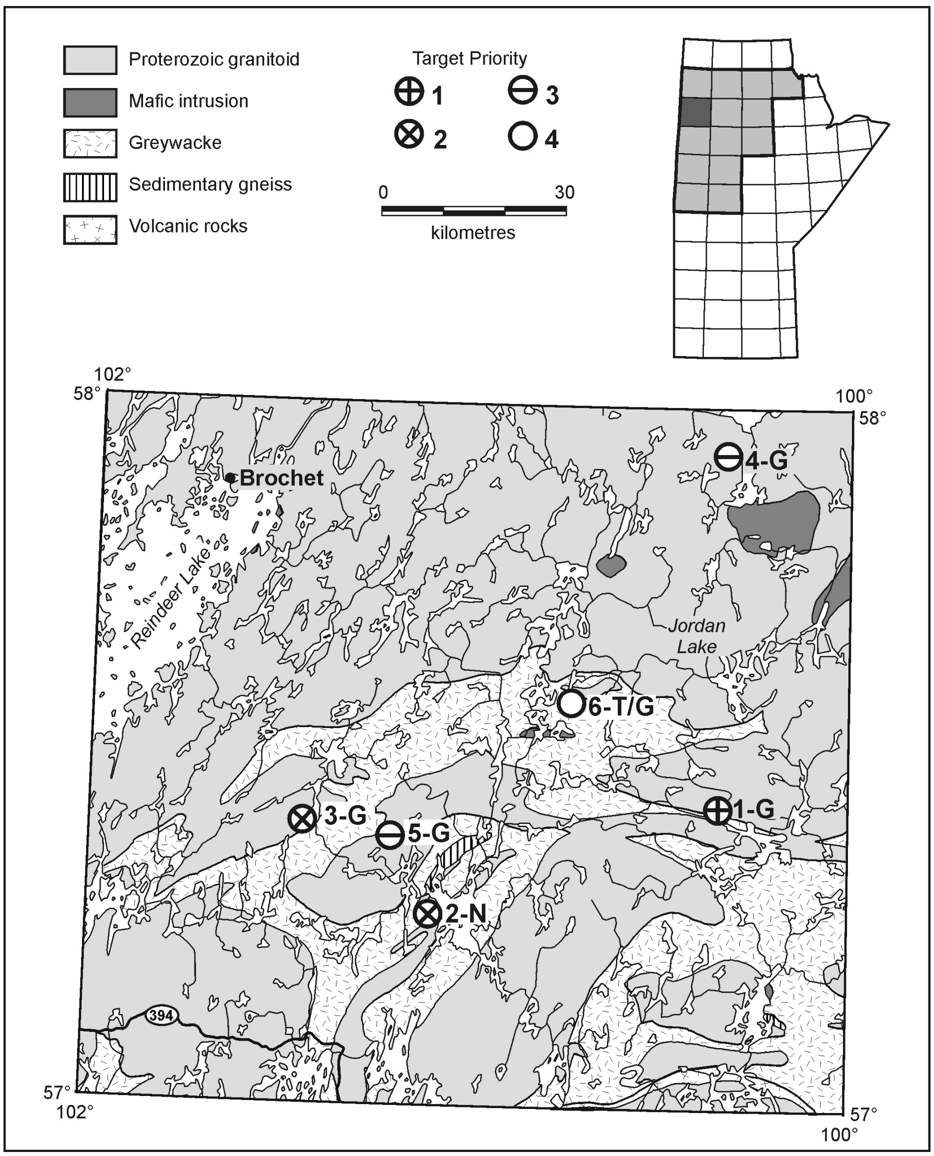

Figure 6: Selected targets for follow-up IOCG investigation, NTS 64F (Brochet).

Table 6: Selected targets for follow-up IOCG investigation, NTS 64G (Big Sand Lake).

ID #	Priority	Location	Surface geology	Mag (gamma)	eK (%)	eTh (ppm)	eU/eTh	Notes
1	3	NE Big Sand Lake	Megacrystic granite(?)	Weak	2.4-2.8	11.0-12.0	0.05-0.1	K/Th high NE of mag
2	3	NE Big Sand Lake	Megacrystic granite(?)	Moderate	2.8-3.0	11.0-12.0	0.05-0.1	K/Th high S/SE of mag
3-G	2	NE Big Sand Lake	Megacrystic granite	Weak	2.4-2.6	10.0-11.0	0.05-0.1	K/Th high E of mag
4	4	W Sedgwick Lake	Overburden	Weak	2-2.2	7.0-8.0	<0.10	K/Th W of mag
5-T/W	2	NE Enatik Lake	Tonalite, metawacke, granite	Weak	2.4-2.6	8.0-9.0	0.1-0.15	Radiometric highs S of mag
6-Z/G	3	E Big Sand Lake	Megacrystic granite, monzonite	Weak	2.4-2.6	8.0-9.0	0.15-0.20	Mag NW of K high
7	4	E Little Sand Lake	Overburden	Moderate	2.2-2.4	6.0-7.0	0.15-0.20	
8-G	3	NE Chipewyan Lake	Granite intrusion of tonalite-granodiorite	Moderate	1.2-1.4	7.0-8.0	0.05-0.10	
9	1	Partridge Breast Lake	Meta-arkose, tonalite, metatexite, nearby intrusions of pegmatite, megacrystic granite	Weak	1.6-1.8	6.0-7.0	0.1-0.15	Faulted zone
10-S/W	3	Partridge Breast Lake	Meta-arkose, wacke, tonalite, nearby pegmatite and diorite intrusions, arkose is bounded to the east by a fault	Weak	--	--	--	No immediately associated radiometric anomalies
11	3	N of Missi Falls	Overburden, likely tonalite	Moderate	1.4	8.0	--	Nearby granite and diorite intrusions
12-T	4	N of Partridge Breast Lake	Tonalite	Moderate	--	5.0	0.15	Nearby diorite intrusion
13-G	3	E of Southern Indian Lake	Megacrystic granite	Moderate	1.0	9.0	0.2	
14-W/Z	3	S of Long Point (Southern Indian Lake)	Metawacke, monzonite	Moderate	1.6	4.0	--	At contact between monzonite and metawacke
15-G	4	S of Long Point (Southern Indian Lake)	Megacrystic granite	Moderate	2.0	--	0.35	Near contact with monzonite
16-B/A	4	E shore, Pine Lake	Metagabbro, amphibolite	Moderate	--	--	--	Likely magnetite related to mafic intrusion
17-W	4	NE of Enatik Lake	Metawacke	Weak	--	7.0	--	
18-W	4	W of Mulcahy Lake	Metawacke	Moderate	--	--	--	Near radiometric 19-W
19-W	4	W of Mulcahy Lake	Metawacke	Weak	--	6.0	--	
20-G	1	W of Little Chipewyan Lake	Granite	Moderate	1.8 & 2.4	9.0	--	Granite intruding metawacke
21-T	3	Little Chipewyan Lake	Tonalite, metawacke	Weak	--	13.0	--	Magnetite tonalite-granodiorite within tonal-ite in contact with metawacke
22-T	1	Little Chipewyan Lake	Tonalite	Weak	1.8	13.0	--	Magnetite tonalite-granodiorite within tonalite
23-G	3	W of Matoo Lake	Granite	Moderate	--	--	--	Granite intruding tonalite
24-Z/Gn	4	W of Denison Lake	Magnetite-bearing granodiorite orthogneiss & megacrystic monzogranite	Weak	2.6	6.0-7.0	0.2	Radiometric anomalies, sublte to no mag anomalies at domain boundary
25	1	Southern Indian Lake between Loon and Strawberry islands	Underwater	Moderate	--	--	--	Mag anomalies in lake, likely associated with granite and metadiorite

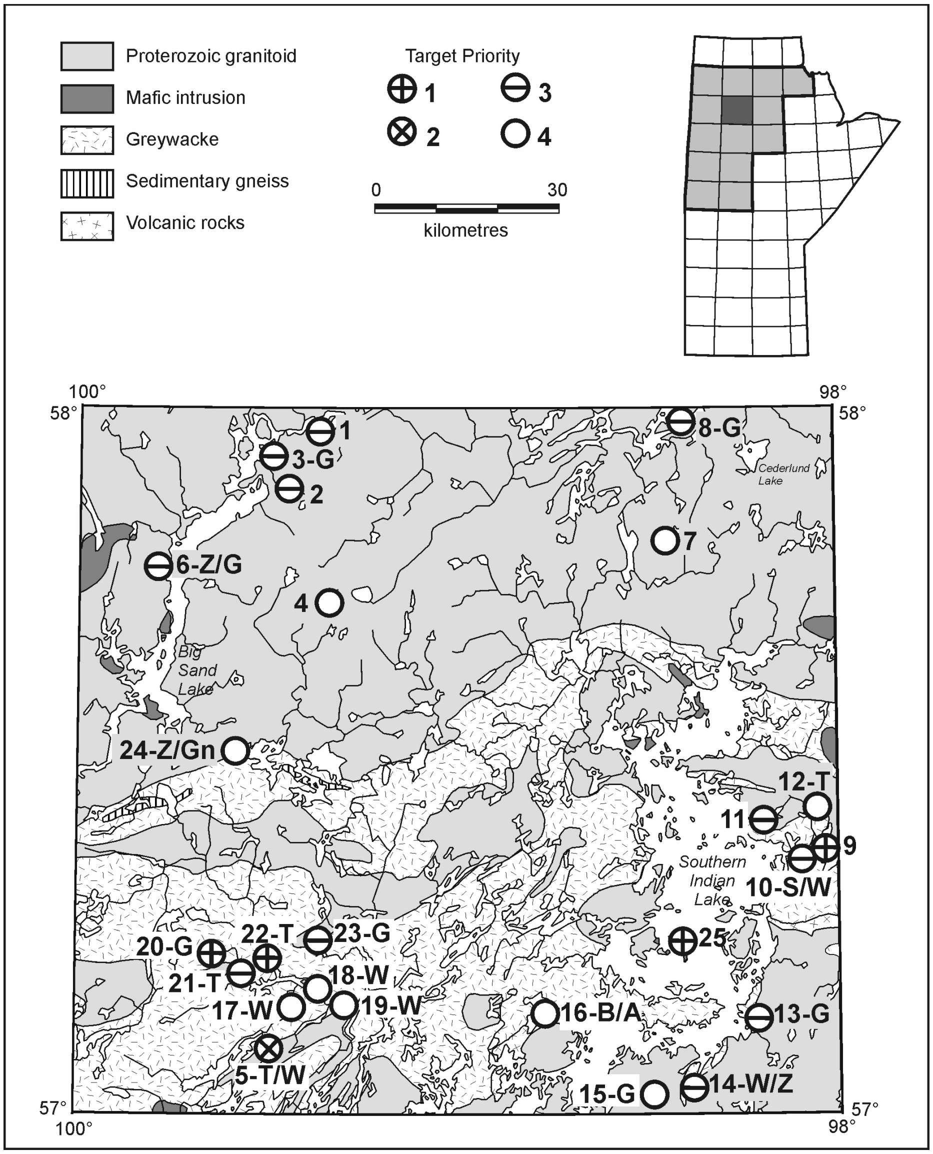

__Figure 7:__ Selected targets for follow-up IOCG investigation, NTS 64G (Big Sand Lake).

deformation.

Quartz+two-feldspar pegmatite dikes are fairly abundant in the Foot Lake Complex. Many of the pegmatite bodies exhibit striking rhythmic compositional banding (Figure 25), which is believed to result from extensional tectonics (at least locally) that facilitated multiple injections of the pegmatite melt into the interiors of the same cooling dikes. Orientation of the dikes is not well defined, although many trend in a north-northeasterly direction and other orientations are also common.

Perhaps the most significant aspect of the Foot Lake Complex is the presence of anomalous radioactivity. Local veins and patches with high radiometric counts are found scattered throughout the Foot Lake exposures (Young and McRitchie, 1990), but the nature of this radioactivity remains essentially undetermined. The stockwork and extensional nature of the igneous and hydrothermal veining are believed to be evidence for a carapace undergoing extensional fracturing above a rising pluton or stock.

Many features in the Foot Lake area are similar to those observed in and around the Eden Lake Carbonatite Complex. This is not surprising, considering that the regional geology, structure and geophysical anomalies extend from Eden Lake to well east of the Foot Lake area. The intrusive stockwork and hydrothermal alteration, however, are less intense (where visited) at Foot Lake than what is now known to occur at Eden Lake. Further work is recommended for this area.

Site 10-G/T: east Opachuanau Lake

A radiometric plus weak magnetic anomaly occurs 1–2 km east of Italy Bay on Opachuanau Lake. Reconnaissance was carried out only in the area around Italy Bay, leaving the specific target site east of the bay uninvestigated. Alkali granite, Na-rich plagioclase porphyry with epidote and pyrite alteration (Figure 26), and fine- to medium-grained igneous felsite with disseminated and vein magnetite±hematite (Figure 27) are exposed along the south and northeast shorelines of Italy Bay (*see also* Mumin and Corriveau, 2004). Epidote-flooded amphibolite and actinolite-garnetite amphibolite are also

Table 7: Selected targets for follow-up IOCG investigation, NTS 64H (Northern Indian Lake).

ID #	Priority	Location	Surface geology	Mag (gamma)	eK (%)	eTh (ppm)	eU/eTh	Notes
1	1	South of Thorsteinson Lake	Under glacial till	Strong		No data		Vicinity of fluorite-bearing, sodic, locally pegmatitic granite
1-W	3	SE shore of Spence Lake	Metagreywacke & intermediate to felsic volcanics	Moderate		No data		Vicinity of pegmatite intrusion, unknown affinity
2	3	East of Solmundsson Lake	Under glacial till	Moderate		No data		Likely associated with Chipewyan Batholith
3	1	N of Freeman Lake	Under glacial till	Strong		No data		As above
4	3	between Ministiko & Minikwakunis Lake	Under glacial till	Moderate		No data		As above
5	1	ESE of Buckland Lake	Under glacial till	Very strong		No data		As above
6	3	S of Etawney Lake	Under glacial till	Strong		No data		As above
7	4	E shore of Kospatawayo Lake	Under glacial till	Moderate		No data		As above
8	4	NW shore of Adam Lake	Under glacial till	Moderate		No data		As above
9	3	N of Adam Lake	Under glacial till	Moderate		No data		As above
10	1	E shore of Pisew Lake	Under glacial till	Very strong		No data		As above
11	3	NW of Abigail Lake	Under glacial till	Strong		No data		As above
1-Z	3	between Wishart & Knifehead Lake	Red syenogranite-quartz monzonite, traces of fluorite	Strong		No data		Near contact with granite
2-Z	3	between Wishart & Knifehead Lake	Red syenogranite-quartz monzonite, traces of fluorite	Moderate		No data		

present regionally around Italy Bay and the western shoreline of Opachuanau Lake. These types of alkalic, calcic and Fe alteration are abundant in regional and intimate association with some IOCG deposits, such as the Great Bear Magmatic Zone, NWT (Goad et al., 2000a, b). Further work is recommended for this region.

Site 12-S: Rat Lake region

Several Fe and/or Cu and Mo occurrences were previously reported in the Rat Lake area. The showings occur within a structurally complex area with young granite, granodiorite, syenite and diorite intruding deformed and metamorphosed sedimentary rocks along the northern margin of the Kisseynew Domain. Attempts to locate most of the occurrences failed, presumably because of the flooding and inaccessibility of many areas. One significant occurrence of ISCG-type mineralization (*see* Mumin and Trott, 2003 for description of ISCG mineralization), however, occurs along the west shore of a southeastern bay. The occurrence contains disseminated to near-massive pyrrhotite and pyrite in sheared metasedimentary rocks with trace chalcopyrite and abundant graphite (Figure 28). The sheared rocks are also host to associated mafic (amphibolite) intrusions.

A zone of wispy sulphide mineralization occurs near the mouth of the Suwannee River at Rat Lake, associated with metasedimentary rocks and quartz veining. The most interesting feature observed, however, was a large boulder of coarse-grained quartz-syenite–quartz-monzonite rock, containing approximately 3% pyrite, that resembles pyritic zones associated with some felsic intrusion–derived mineralization.

Summary of field observations from selected targets in NTS 64C (Granville Lake)

Site 1-W/X: Wolfcub Lake

Coincident weak to moderate magnetic and radiometric anomalies are associated with pegmatitic masses intruding Kisseynew metasedimentary rocks southeast of Wolfcub

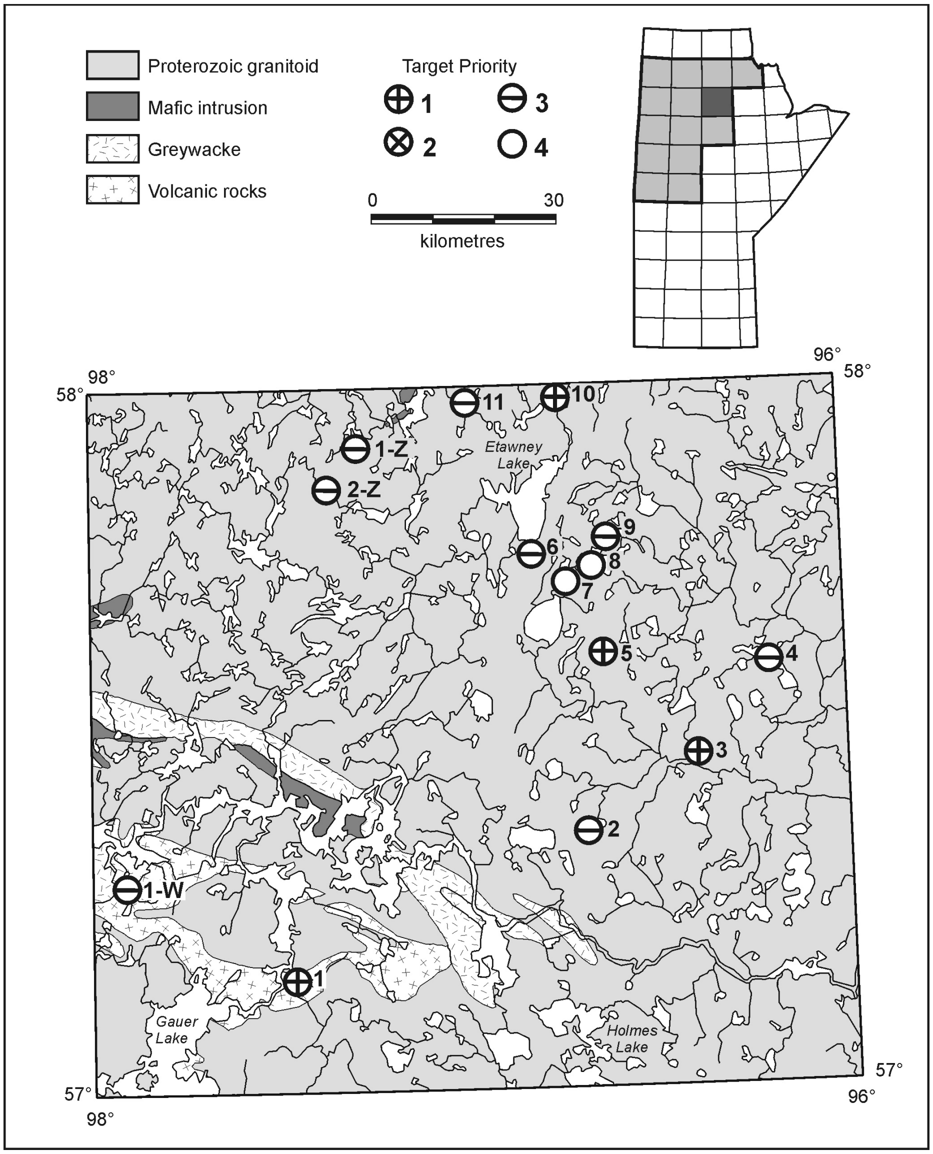

Figure 8: Selected targets for follow-up IOCG investigation, NTS 64H (Northern Indian Lake).

Lake. The small area within the region that was examined is composed of Kisseynew metasedimentary rocks, porphyroblastic granodiorite and small magnetite-bearing mafic to ultramafic dikes. The desired target site, however, was not accessible during the present study. No conclusions can be drawn about this area.

Site 3-W/X: Trophy Lake

The anomaly of interest occurs in an arcuate trend parallel to and southwest of the southwest shoreline of Trophy Lake. The target is similar to that at Wolfcub Lake, with moderate magnetic and radiometric anomalies coincident with an arcuate pegmatitic intrusion into metasedimentary rocks. The area of prime interest was not accessible during the present study; however, where visited, the adjacent shoreline of the lake exposed metasedimentary rocks intruded by quartz+two-feldspar pegmatite dikes. No conclusions can be drawn with respect to the Trophy Lake anomaly.

Site 2-W: Allen Lake

The Allen Lake anomaly is a circular, weak magnetic feature with coincident (adjacent) radiometric signatures in regional Kisseynew metasedimentary rocks. The circular magnetic feature lies hidden beneath a round bay along the west shore of Allen Lake. The adjacent shoreline, where visited, is dominated by metasedimentary rocks intruded by mafic dikes and granitic pegmatite bodies. One of the pegmatite dikes contained minor amounts of blue-green beryl crystals. No conclusions can be drawn regarding this site.

Site 7-X/T: Central Granville Complex

The Central Granville Complex refers to an ovoid, differentiated felsic complex emplaced into Sickle Group metasedimentary rocks of the northern Kisseynew Domain near the north-central part of Granville Lake. The complex measures approximately 9 km by 3.5 km and is compositionally zoned, with a tonalite core, granodiorite intermediate zone and

Table 8: Selected targets for follow-up IOCG investigation, NTS 64C (Granville Lake).

ID #	Priority	Location	Surface geology	Mag (gamma)	eK (%)	eTh (ppm)	eU/eTh	Notes
1-W/X	1	SE Wolfpack Lake	Circular pegmatite intrusion in metawacke	Weak	2.2-2.4	9.0-10.0	0.5-0.55	Rare K-eU/eTh correlation
2-W	3	Allen Lake	Metawacke & granite	Weak	1.6-1.8	13.0-14.0	0.1-0.15	
3-W/X	1	Trophy Lake	Circular pegmatite intrusion in metawacke and metasandstone	Weak	1.4-1.6	11.0-12.0	0.25-0.30	Mag mimics shape of pegmatite
4-G/S	3	N Trophy Lake	Granite intrusion between grandodioirite and metasandstone	Weak	1.6-1.8	10-11.0	0.25-0.30	Mag anomaly centred in granite
5-Z/X	1	E Eden Lake	Monzonite and pegmatite within granodiorite	Weak	2.2-2.4	9.0-10	0.2-0.35	Mag coincides with pegmatite intrusions, K with sheared monzonite
6-W	3	SW Russell Lake	Metawacke	Weak	1.4	3.0	--	Anomaly adjacent to alkaline complex
7-X/ G/T	3	Granville Lake	Pegmatite, granite and tonalite gneiss	Weak	--	--	--	Possible segregation in granitic intrusion

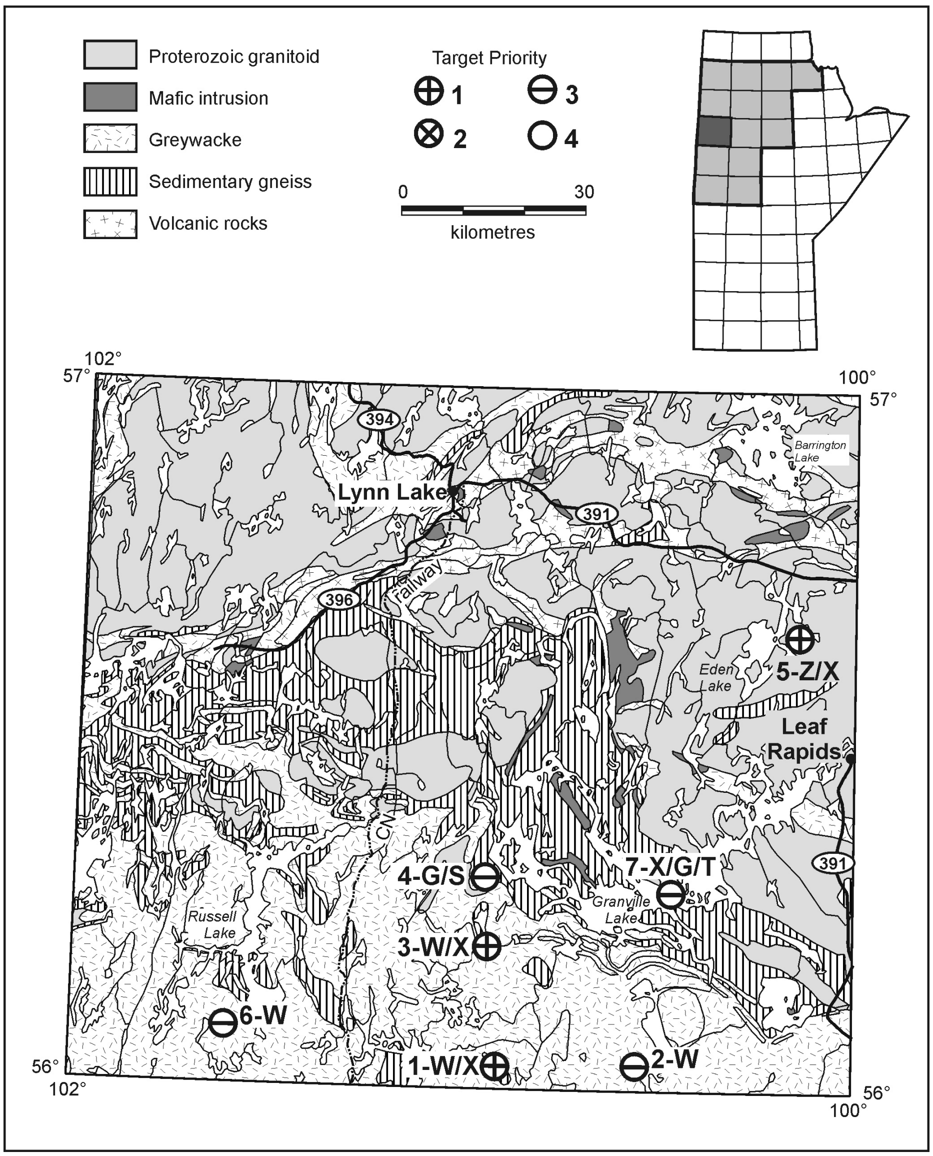

Figure 9: *Selected targets for follow-up IOCG investigation, NTS 64C (Granville Lake).*

Table 9: Selected targets for follow-up IOCG investigation, NTS 64B (Uhlman Lake).

ID #	Priority	Location	Surface geology	Mag (gamma)	eK (%)	eTh (ppm)	eU/eTh	Notes
1-G	3	NW South Bay	Granite intruding granodiorite	Weak	2.0-2.2	11.0-12.0	0.15	
2-G	1	E Karsakuwigamak Lake	Granite intruding granodiorite, rimmed by volcanics (basalt, rhyolite)	Strong	1.4-1.6	6.0-7.0	0.15-0.20	Mag high in granite
3-G	4	W Gauer River	Granite intruding tonalite	Moderate	1.4-1.6	5.0-6.0	0.15-0.20	
4-G	4	N Opachuanau Lake	Granodiorite-granite intruding tonalite	Moderate	0.8-1.0	6.0-7.0	0.15-0.20	Mag NE of radiometrics
5-G/Z	4	Northern part of Southern Indian Lake	Megacrystic granite, monzogranite, metasandstone	Moderate	1.0-1.2	5.0-6.0	0.1-0.15	Calcsilicate in the metasandstone
6-W/S	4	W shore of Leftrook Lake	Metawacke, metasandstone	Weak	1.4-1.6	11.0-12.0	0.1-0.15	Mag E of radiometrics
7-G	3	NW shore of Leftrook Lake	Porphyritic granite intruding metasandstone and gneissic granodiorite	Moderate	0.8-1.0	6.0-7.0	0.1-0.15	Fault runs along western margin of mag
8-G/T	1	N Cousins Lake	Megacrystic granite, near contact with tonalite (mafic meta-volcanics in area?)	Strong	1.8-2.0	3.0-4.0	0.2-0.25	Mag E of radiometrics
9-G	4	NW Churchill River	Granite intruding tonalite, nearby amphibolite	Negative	2.2-2.4	9.0-10.0	0.2-0.25	Vague, large-scale target area
10-G/T	3	E of Opachanau Lake	Tonalite, quartz diorite, granodiorite	Weak	1.4-1.8	10.0-12.0	0.4-0.45	Coinciding radiometric and magnetic anomalies (very high uranium)
11-G	3	W of Karsakuwigamak	Granite set in meta-volcanics	Strong	1.6-1.8	6.0-7.0	0.4-0.45	Ruttan mine area; volcanoplutonic system?
12-S	1	SW end of Rat Lake	Iron, molybdenum showings set in metasediments, granite, gabbro, etc., around Rat Lake	Jumbled collage of lows and moderate highs	--	--	--	Geologically complex area; showings are mostly on lakeshore
13-D (a,b,c,d)	1	N and W of Rat Lake	Black Trout diorite intrusives set in granitoid	Complex magnetics	--	--	--	Apatite- and magnetite-enriched diorite
14-G	1	W of Opachuanau Lake	Porphyritic granite body	Weak	Anomalous; mimics shape of pluton	--	--	High-uranium anomaly super-imposed on K anomaly over felsic pluton; anomaly extends to Eden Lake

pegmatitic northern margin (Manitoba Energy and Mines, 1986). There have been local reports of minor "copper-vein mineralization" and "porphyry-style copper" mineralization in the vicinity of the complex. Reconnaissance around the islands and shoreline of Granville Lake near and within the complex, and of the centre of the complex, failed to locate any evidence of mineralization or hydrothermal alteration that could be directly linked to an IOCG- or porphyry-copper–type system. Nevertheless, portions of the complex do show evidence of being moderately potassic (Figure 29). Also, granitic dikes intrusive into metasedimentary rocks peripheral to the complex are locally associated with ISCG-style mineralization. Only a small portion of the area of interest was examined and further work in the area should not be ruled out.

Site 5-Z/X: Eden Lake

The Eden Lake anomaly is characterized by coincident, moderate magnetic and strong radiometric eK anomalies within regionally extensive radiometric eU and eTh highs. Hostrocks of the Eden Lake area were reported to be alkaline in nature and dominated by aegirine-augite monzonite. Rare earth element–bearing pegmatite, syenite, alkali granite and aplite also intrude the complex, which itself is regionally hosted in biotite granite and megacrystic granite (Cameron, 1988; McRitchie, 1989; Halden and Fryer, 1999). Reports of high radiometric counts, elevated REE concentrations, and one small high-grade vein date back to reports by McRitchie (1988, 1989). The association of coincident geophysical anomalies and a

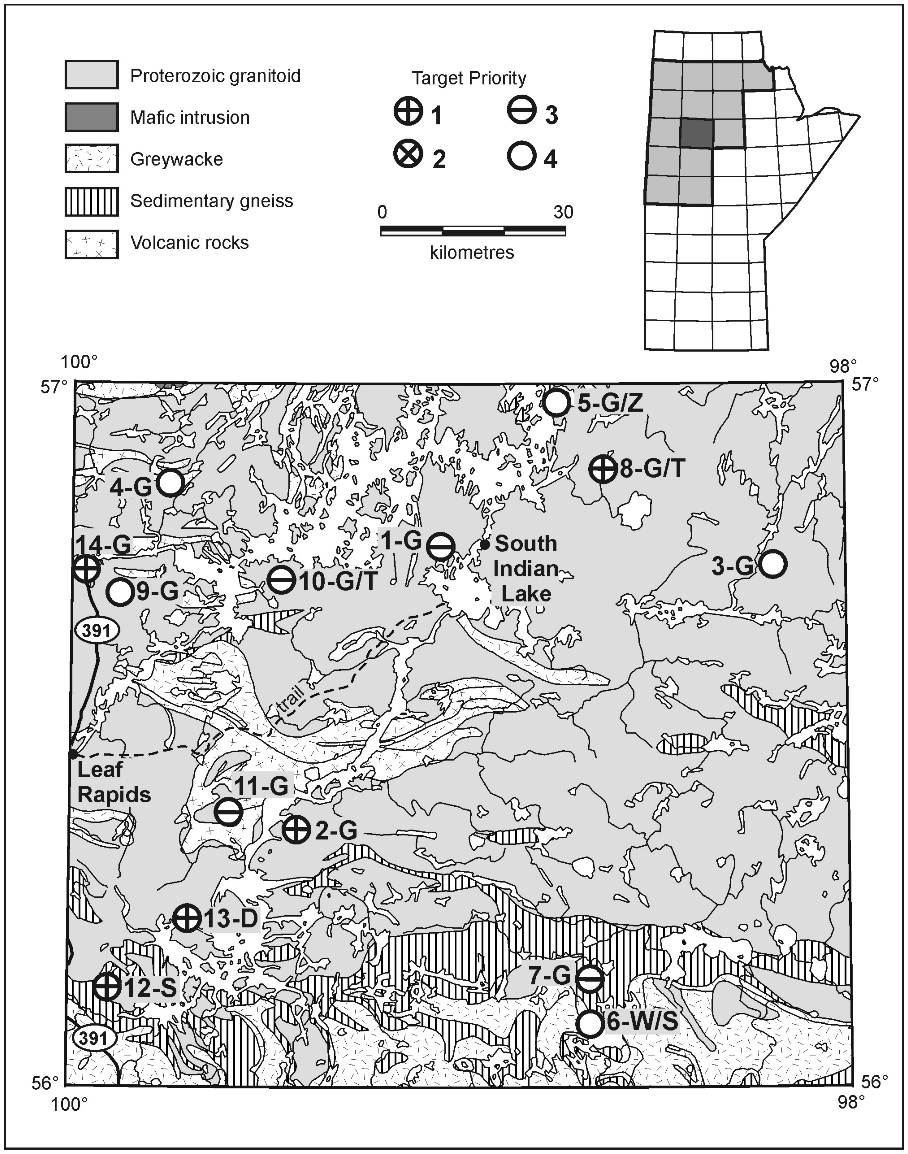

Figure 10: *Selected targets for follow-up IOCG investigation, NTS 64B (Uhlman Lake).*

late alkaline intrusive complex with known REE and U-Th enrichments made Eden Lake a high-priority target for follow-up field investigations.

Initial field reconnaissance at Eden Lake in June of 2002 revealed an extensive and complex stockwork of mafic to felsic igneous rocks with a superimposed stockwork of hydrothermal veining (Figure 30). The initial reconnaissance was followed with systematic detailed mapping, which led to the unexpected discovery of carbonatite dikes, pods and veins, all carrying abundant REE-rich apatite, and recognition of the greater region as a carbonatite complex (Figure 31). Further work revealed a series of narrow but high-grade hydrothermal REE veins exposed over an area of 2 km by several hundred metres, as well as REE-apatite-clinopyroxene veins (Figure 32). The Eden Lake Carbonatite Complex is presently known to cover an area in excess of 30 km^2. It consists of a central complex, extending over at least 8 km^2, that comprises intense igneous and hydrothermal veining and alteration, superimposed in multiple injections upon many successive events. Rare earth element–bearing carbonatite and alteration are now known to occur throughout most of the 8 km^2 core of the complex as patchy and irregular zones of alteration, veins and dikes up to 4 m in width. The igneous rocks intrude in a general evolutionary trend from early ultramafic and mafic rocks through to intermediate and late alkali felsic rocks. The intense igneous and hydrothermal veining form a shattered carapace believed to overlie a large carbonatite or carbonatite-bearing igneous body. The widespread hydrothermal alterations and REE-rich veins are typical of those derived by fluids emanating from carbonatite magmas.

Assays of REE-rich veins grade up to 169 000 ppm total REE, 8800 ppm Th+U, and 5300 ppm Y. Apatite-rich segregations from the carbonatite bodies grade up to 19 300 ppm total REE (~50% apatite+carbonate, pyroxene and feldspar), and samples of narrow apatite-pyroxene veins contain up to 27 000 ppm REE (~65% apatite+pyroxene and feldspar). Additional information on the Eden Lake Carbonatite Complex can be found in Mumin (2002a), Mumin and Camier (2003),

Table 10: Selected targets for follow-up IOCG investigation, NTS 64A (Split Lake).

ID #	Priority	Location	Surface geology	Mag (gamma)	eK (%)	eTh (ppm)	eU/eTh	Notes
1-S	4	W Strong Lake	Metasandstone, metawacke, amphibolite	Moderate	0.8-1.0	5.0-6.0	0.15-0.20	
2-S/W	4	W Pearson Lake	Metasandstone, metawacke	Moderate	0.6-0.8	5.0-6.0	0.1-0.15	Mag over sandstone (very common)
3	3	SE shore Baldock Lake	Overburden	Strong	1.2-1.4	4.0-5.0	0.1-0.15	
4	3	NW White Stone Lake	Overburden	Strong	0.8-1.0	3.0-4.0	0.2-0.25	
5-W	4	NW Campbell Lake	Magnetic metawacke, tonalite	Strong	___	4.0-5.0	0.2-0.25	
6	3	NW Wernham Lake	(?) nearby syenogranite	Very strong	0.8-0.1	4.0-5.0	0.2-0.25	
7-G	4	N shore Caldwell Lake	Syenogranite, granodioirite	Moderate	___	2.0-3.0	0.2-0.25	Mag located on boundary between Chipewyan & Leaf Rapids domains
8	3	SW Waskaiowaka Lake	Overburden	Strong	0.8-1.0	5.0-6.0	0.1-0.15	Very strong magnetics
9-Trnd	3	Boundary b/w Chipewyan and Leaf Rapids domains	Glacial till	Moderate	0.8-1.2	3.5-5.0	0.1-0.2	String of moderate K anomalies spatially parallel to domain boundary
10	3	Northwest of Christie Lake	Glacial till, target is probably located in the Chipewyan syenogranite batholith	Strong	0.6-0.8	7.0-8.0	0.15-0.2	Strong magnetics with moderate K and eTh coincident anomalies
11	1	S of Baldock Lake	Glacial till	Weak	1.4-1.6	5.0-6.0	--	Large high-K anomaly superimposed with an area of low eTh/K; large hydrothermal system?

Mumin and Corriveau (2004) and work in preparation.

The discovery at Eden Lake of carbonatite bodies enriched in REE apatite and high-grade veins enriched in REE britholite and allanite is presently one of the most interesting findings of the Manitoba IOCG scoping study. Many investigators have noted a close relationship of some carbonatite bodies with some types of IOCG deposits (Groves and Vielreicher, 2001). For example, the Bayan Obo carbonatite-derived REE deposits in China have long been grouped with IOCG-type systems, largely due to their association with abundant Fe oxides. They are currently the world's greatest source of REE metals. For more information concerning the Bayan Obo deposit, see Campbell and Henderson (1997), Smith and Chengyu (2000) and Nie et al. (2002). Other interesting IOCG-carbonatite associations include the giant Phalaborwa polymetallic deposit in South Africa (Vielreicher et al., 2000; Harmer, 2000; Groves and Vielreicher, 2001).

Several important conclusions with respect to this scoping study can be drawn from the Eden Lake discoveries:

- Where there is one carbonatite, there is likely to be more within the vast and complex terranes of the Trans-Hudson Orogen.
- The presence of one type of IOCG-related mineralization bodes well for the discovery of other styles of IOCG mineralization.
- The regional geophysical and geological survey compilations and the target selection undertaken in this study can apparently identify igneous-related mineralizing systems.

The Eden Lake Carbonatite Complex was under active exploration and investigation at the time this report was being written.

Iron-sulphide copper-graphite (ISCG) mineralization in Manitoba

A unique style of iron-sulphide copper-graphite (ISCG) mineralization (Mumin and Trott, 2003) is exposed at numerous locations along the northern margin of the Kisseynew Domain, where at least 15 outcrop, roadcut and quarry exposures were examined across a zone extending for approximately 160 km. The style of mineralization at most locations is very similar and hosted within garnet-biotite gneiss (probable metaturbidite-metagreywacke). The mineralization occurs within late cataclastic to brittle-ductile structures that cut the regional high-grade metamorphic fabric, and is often in direct association

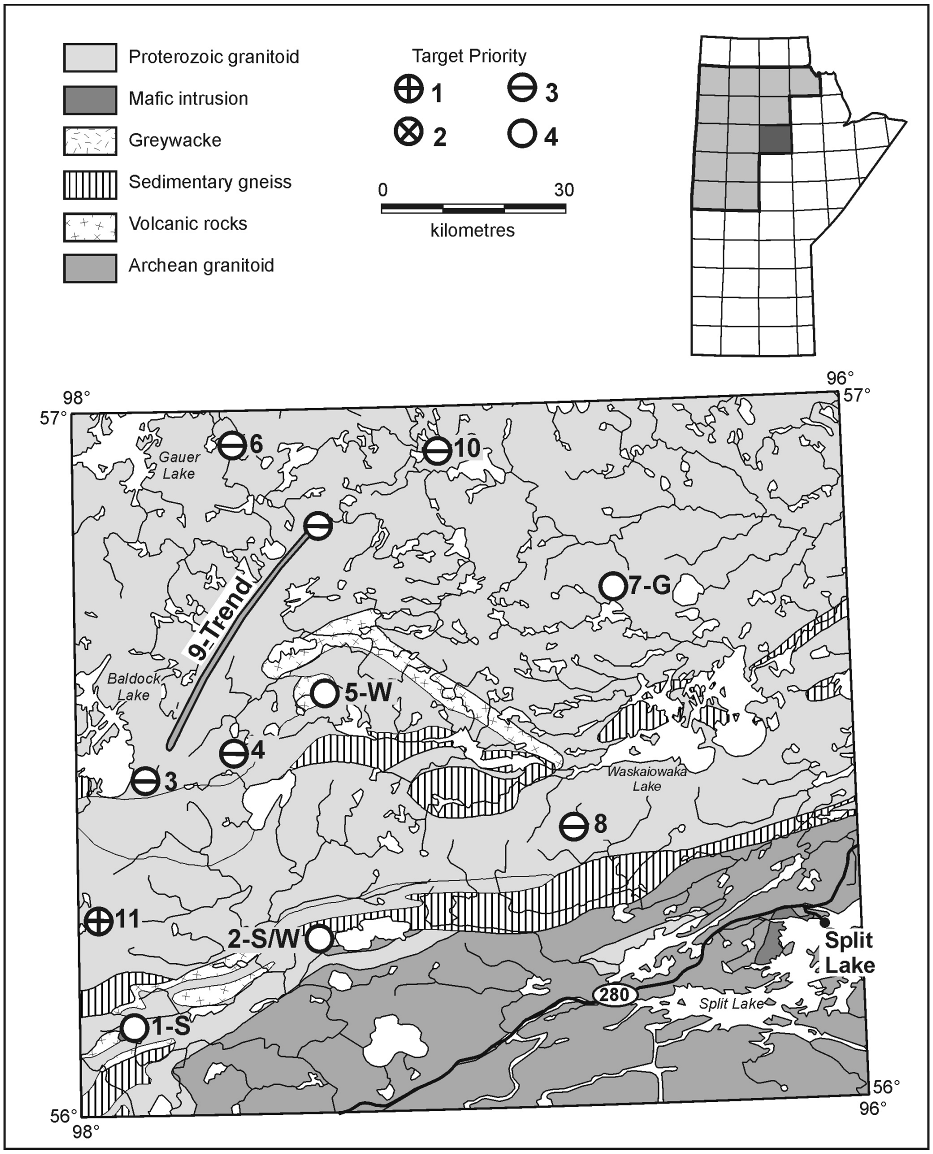

Figure 11: *Selected targets for follow-up IOCG investigation, NTS 64A (Split Lake).*

with felsic and/or mafic intrusions (Figures 33, 34). These zones are characterized by Fe sulphides (pyrrhotite with subordinate to minor pyrite) infilling along the structures. Total sulphides range from trace amounts of disseminated mineralization up to approximately 80 modal% of the rock, with typically about 0.1 to 7 modal% of the sulphide occurring as chalcopyrite that is intimately intergrown with pyrrhotite. Geochemical analyses show low to moderate Cu enrichments in all analyzed showings, ranging up to 8718 ppm, and Ag values up to 5.4 g/t. Other sulphide minerals identified in one or more of the showings include trace amounts of molybdenite, pentlandite, arsenopyrite and sphalerite.

All ISCG deposits contain abundant graphite (2–20 modal%), commonly as shiny, metallic-looking platelets and flakes. The graphite is intimately intergrown with sulphides and associated sheared and altered hostrocks, including silicified and carbonate-altered zones (Figures 35, 36). Minor Fe oxides are present in some showings as ilmenite and magnetite. They are also occasionally present in minor amounts within the garnet-biotite schist. Most of the Fe oxide is presently thought to be metamorphic and/or hydrothermal in origin. Other gangue minerals intergrown with the mineralization include quartz, albite, pyroxene, biotite, phlogopite, amphibole, carbonate, chlorite, epidote, sericite, cordierite, maghemite and some combination of pinite, chlorophaeite and iddingsite. The mineralization is ubiquitously associated with quartz veining and/or some form of silicification. In some showings, the mineralization is skarn-like, with abundant pyroxene-albite-biotite/phlogopite hosting pyrrhotite-graphite and minor chalcopyrite.

A sample of carbonate-rich material adjacent to a pyroxenite intrusion into the Notigi-1 quarry mineralization has a mineral assemblage comparable to some olivine carbonatite bodies (Figure 37). A matrix of 60% carbonate contains fresh euhedral to subhedral olivine, phlogopite, clinopyroxene and amphibole. This carbonate-rich rock hosts approximately 12% pyrrhotite, 3% graphite, minor chalcopyrite and sphalerite, and trace amounts of ilmenite, apatite and zircon (Data Repository item 2005002, sample NTG-1A).

Table 11: Selected targets for follow-up IOCG investigation, NTS 63N (Kississing Lake).

ID #	Priority	Location	Surface Geology	Mag (gamma)	eK (%)	eTh (ppm)	eU/eTh	Notes
1-Z	1	NW Burntwood Lake	Aegrine-augite syenite	Weak	1.8	14.0	0.15	Intrudes migmatitic metawacke associated with major structural lineaments
2-E	1	NW Burntwood Lake	Enderbite	Weak	2.2	9.0	--	Associated with at least two major structural lineaments and a spatially associated radiometric trend intruding migmatitic metawacke
3-W/E	3	W Highrock Lake	Enderbite-metawacke-granite	Weak	2.0	7.0	0.3	
4-W	3	Between Channel of Churchill River & Pukatawagan Lake	Metawacke	Weak	2.0	11.0-12.0	0.15	Various granitic and enderbitic intrusions of varying ages, occurs along radiometric trend
5-W/E	4	NW Flatrock Lake	Metawacke-enderbite	Weak	1.2	9-10	0.15	Occurs along radiometric trend
6-W	4	E Nelson Lake	Metawacke	Weak	0.8 (low)	11.0	0.1-0.15	May be on continuous trend with nearby structural lineament, associated with small granitic intrusions
7-W	4	E Nelson Lake	Metawacke	Weak	1.6-1.4	9.0	0.1 (low)	As above
8-W/G	1	E Flatrock Lake	Metawacke-granite	Weak	2.4	20.0	0.1 (low)	K high and extreme Th high adjacent to extreme lows occurs along radiometric trend
9-E	3	SW Flatrock Lake	Enderbite	Weak	2.4	6.0 (low)	0.2	Associated with major fault, Th low is super-imposed on magnetic anomaly, K high occurs on opposite side of fault in metawacke with nearby granite bodies
10-E/W	1	Touchbourne Lake	Enderbite-metawacke	Weak	2.0	10.0	0.2	Wacke intruded by enderbite and granite bodies, proximal to major faults
11-G/W	1	E of Burntwood Lake	Granite-metawacke	Moderate	2.0	10.0	0.1 (low)	Radiometric anomalies proximal to major fault zones, mag anomaly overlies metawacke and granite body with nearby granite and enderbite bodies
12-G/W	4	S of Burntwood Lake	Granite-metawacke	Weak	1.6	6.0-7.0	0.15-0.1	Multiple intrusions in metawacke, nearby enderbite
13-G/W	4	S of Burntwood Lak	Granite-metawacke	Moderate	1.4	5.0-6.0	0.2	Occurs at contact between migmatitic metawacke and granitic body
14-W	3	S of Burntwood Lake	Metawacke	Weak	1.8	9.0	0.15	Migmatitic metawacke with nearby granitic intrusion

The presence of ubiquitous Cu and the igneous, structural and hydrothermal association of this mineralization raise the possibility of an igneous-hydrothermal or IOCG-type association, and bring into question previous suggestions of a syngenetic origin for the sulphide mineralization (i.e., sedimentary or exhalative stratabound iron formation). The ISCG deposits discussed here occur in rocks that are thought to be remnants of a deeply buried and subsequently exhumed accretionary complex, with an abundance of documented late felsic, intermediate and mafic intrusions into the sequence (Manitoba Energy and Mines, 1986, 1988, 1989).

The similarity of Manitoba ISCG mineralization to some pyrrhotite-hosted IOCG deposits in Australia, India and Chile is of particular interest (Haynes, 2000; Williams and Pollard, 2002; Knight et al., 2002). In a general review of IOCG deposits, Haynes (2000) subdivided IOCG deposits into two end-member groups that he referred to as IOCG (iron-oxide copper-gold) and ISCG (iron-sulphide copper-gold) deposits. He described the iron-sulphide copper-gold deposits as forming in reduced, graphite-bearing terranes, whereas the IOCG deposits form in more oxidized hostrocks. Deposits of the Ketri district in India have also been referred to as belonging to the ISCG subgroup by Knight et al. (2002). In both cases, the characteristics of the ISCG mineralization described

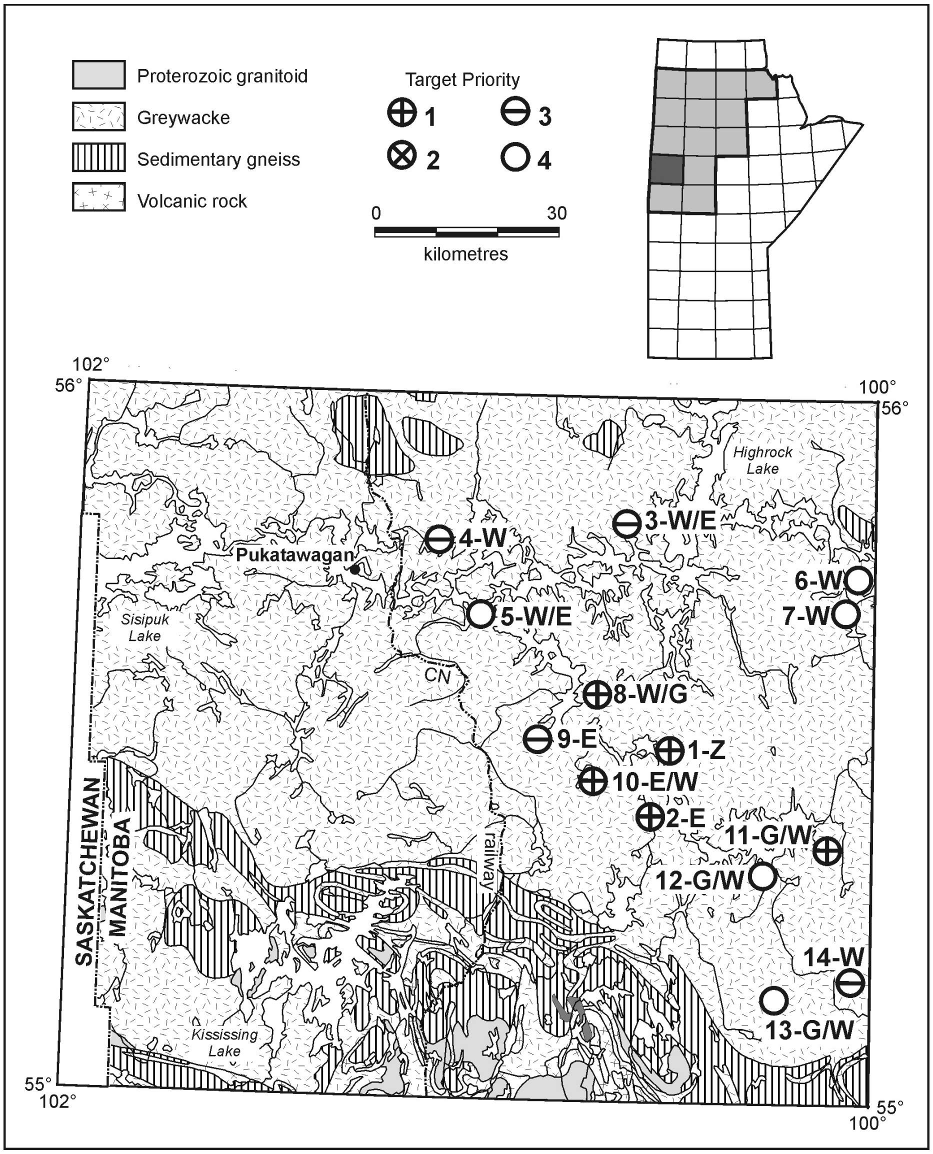

***Figure 12:** Selected targets for follow-up IOCG investigation, NTS 63N (Kississing Lake).*

by Haynes (2000) and Knight et al. (2002) are quite similar to the Manitoba ISCG mineralization described here. Both authors included a list of very significant deposits within their ISCG classification, including Mt. Isa, Australia (255 million tonnes at 3.3% Cu and 0.1 g/t Au); Mammoth-Esperanza, Australia (14 million tonnes at 4.5% Cu); Eloise, Australia (3.2 million tonnes at 5.8% Cu and 1.5 g/t Au); El Soldado, Chile (70 million tonnes at 1.8% Cu); and the Ketri copper belt, India (140 million tonnes at 1.1–1.7% Cu and 0.5 g/t Au). In light of economic examples of apparently similar types of mineralization, it is reasonable to conclude that there is a very large and completely unexplored district within the Kisseynew Domain of the Trans-Hudson Orogen in Manitoba that has potential to host similar types of deposits.

The presence of unaltered, igneous-textured olivine carbonatite intimately associated with ISCG mineralization at Notigi further supports an igneous-hydrothermal origin. It also raises a host of intriguing questions and possibilities regarding 1) the abundance and distribution of carbonatite bodies in the Trans-Hudson Orogen (Notigi is the second probable carbonatite-associated (?) discovery after Eden Lake); and 2) the spatial and/or genetic relationship between carbonatite and the IOCG and ISCG styles of mineralization. Further information on the Manitoba ISCG mineralization is given in Mumin and Trott (2003).

Other evidence of igneous-hydrothermal mineralization

Other geological features indicative of igneous-hydrothermal mineralization were observed at several localities during the course of the scoping study. An interesting intrusive complex is located about 75 km southeast of Leaf Rapids. It consists of another large (kilometre-scale), young and well-preserved felsic stockwork intruded into regional metasedimentary rocks of the northern Kisseynew Domain (Figure 38). The intrusion stockwork comprises granite, aplite and intermediate phases with arkosic hostrocks and abundant Fe staining (Figure 39). It was not possible to sample deep enough below the Fe-stained zones during the present study to determine the

Table 12: Selected targets for follow-up IOCG investigation, NTS 63O (Nelson House).

ID #	Priority	Location	Surface Geology	Mag (gamma)	eK (%)	eTh (ppm)	eU/eTh	Notes
1-G	1	SW tip of Wapisu Lake	Porphyroblastic granite intruding metawacke	Moderate	2.6-2.8	11.0-12.0	0.1-0.15	Crosscutting faults nearby
2-G	1	W Atik Lake	Granitic intrusion in metawacke & meta-sandstone	Moderate	1.4-1.6	7.0-8.0	0.05-0.2	Faulting present
3	3	W Odei River	Overburden	Moderate	2.0-2.2	5.0-6.0	0.15-0.20	
4-G	3	NW Setting Lake	Gneissic biotite granite (pegmatite patches) intruding metawacke	Moderate	1.6-1.8	10.0-11.0	0.1-0.15	
5-G	2	West of Eyinatik Lake	Migmatite west of tonalite intrusion	Weak	2.0-2.2	8.0-9.0	0.2-0.25	
6-G	3	Hambone Lake	Granite intrusion into Archean, peripheral mafic dikes & iron-formation	Moderate	1.0-1.2	5.0-6.0	0.1-0.15	Iron formation facies unspecified; Ni-Cu showing (see bedrock compilation)
7-G/W	3	N Wimapedi Lake	Granite intrusion in metawacke	None	1.8-2.0	10.0-11.0	0.2-0.25	Granite possibly pegmatite, other K highs in granite
8-G/W	1	NW of Five Mile Lake	Granite intrusions in metawacke	Weak	1.6-1.8	9.0-10.0	0.15-0.20	Coincident K and eTh anomalies directly E of a segregated granite pluton displaying a pegmatitic outer phase

source of the oxidation. Mineralized rocks do, however, occur in the same general vicinity, including the Cu-quarry ISCG showing (Figure 40; *see also* Mumin and Trott, 2003) and exposures of hematitic and sulphide-bearing, coarse-grained to pegmatoid granite (Figure 41).

Another example of igneous-hydrothermal mineralization is illustrated in Figure 42, from Highway 391 east of Nelson House. A young granitic dike, surrounded by a selvage of sulphide mineralization, grades upward into quartz veining and sulphides along the shear that hosts the intrusion. This type of showing illustrates on a very small scale the type of feature that might be of economic interest if present on a much larger scale. Perhaps one of the more important observations is the overall abundant occurrence of young felsic intrusions and their association with hydrothermal alteration and mineralization.

Conclusions and recommendations

The Trans-Hudson Orogen comprises many geotectonic terranes that are prospective for IOCG and other igneous-hydrothermal types of deposits (*see also* Mumin and Corriveau, 2004). Examination and compilation of regional geological and geophysical survey data have identified 142 sites for follow-up fieldwork; however, only 13 of these targets have been visited to date and, for many of these, the reconnaissance examination has been minimal. In addition to the fourteen 1:250 000-scale NTS areas considered in this study, seven more areas that are entirely or partially within the Trans-Hudson Orogen have yet to be examined. Prospective terranes of the Trans-Hudson Orogen extending into Saskatchewan and Nunavut have not been investigated. This study demonstrates that even regional-scale compilation of IOCG-associated geophysical and geological features can identify numerous target areas that have shown characteristics of, and even potential to host, this type of mineralization. Nevertheless, the most effective approach has been to combine the regional compilations with field reconnaissance and ultimately persistence in continued follow-up and detailed work.

It has also been demonstrated that many important IOCG-related features and potential mineralization are only identified through persistent fieldwork, because many important geological features of interest do not show up on the regional-scale surveys. A considerable number of other subtle or noncoincident anomalous features detectable on the regional survey data were not included in the present list of 142 target sites, even though some of these might originate from IOCG or igneous-hydrothermal systems.

Persistent and detailed fieldwork has resulted in two particularly significant findings. The discovery of the Eden Lake rare earth element (REE)–enriched carbonatite complex is a first for Manitoba, and opens the door to exploration for an entirely new deposit type in the province. Numerous carbonatite complexes have been identified in Ontario, and the discovery of the Eden Lake Carbonatite Complex suggests that the lack of carbonatite in Manitoba is only apparent, and that others may be present. The discovery also bodes well for IOCG deposits in general, considering the known association between IOCG systems and carbonatite complexes. It is most significant that the Eden Lake Complex was found to occur along a major deformation

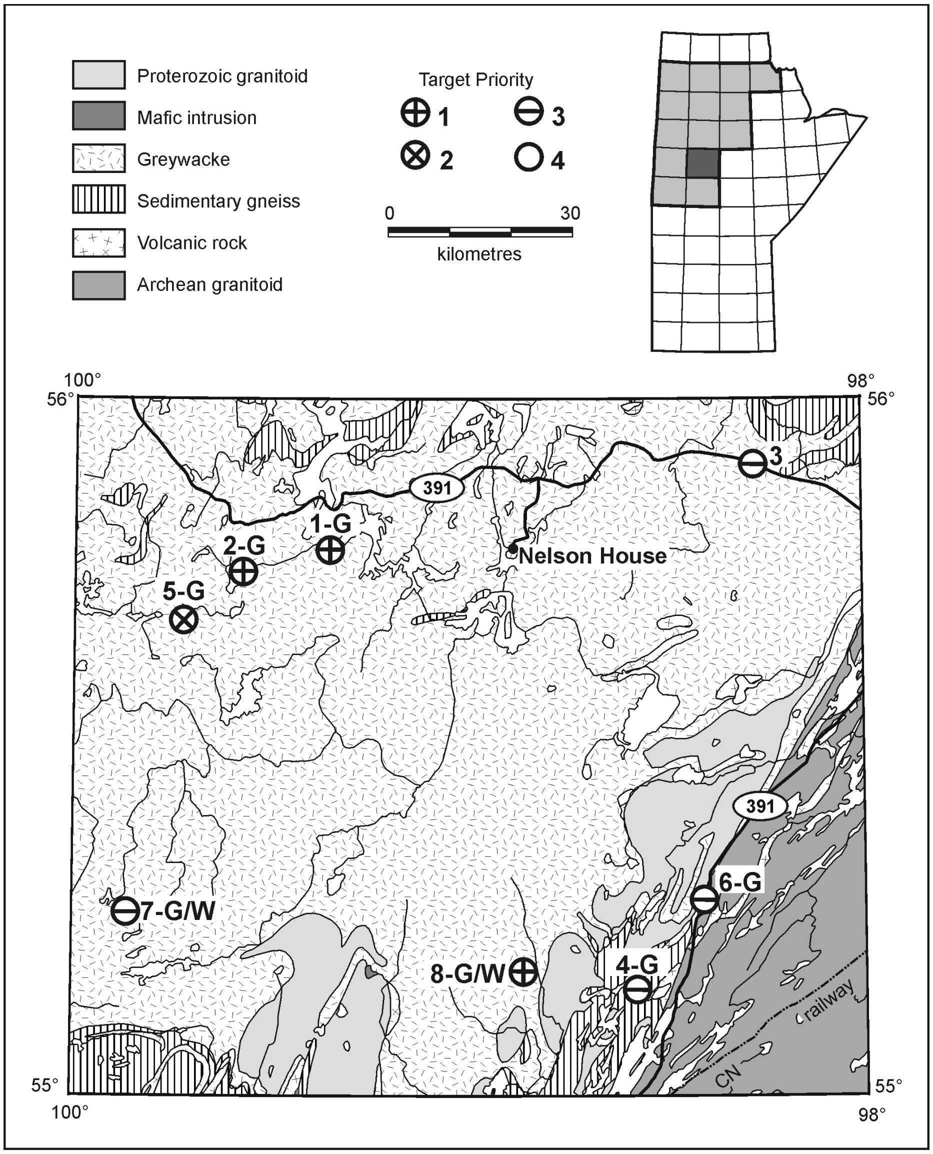

Figure 13: *Selected targets for follow-up IOCG investigation, NTS 63O (Nelson House).*

corridor, the Eden deformation zone, described by Mumin and Corriveau (2004). It is even more intriguing that deep-crustal seismic profiles penetrating to the upper mantle across the southern Trans-Hudson Orogen and across the Olympic Dam deposit in Australia show similar and dramatic deep-seated crustal offsets, and large low-response zones that may be igneous diapirs (White et al., 2000; Lyons et al., 2004; Mumin and Corriveau, 2004). These crustal breaks are situated beneath both the Eden deformation corridor and the Olympic Dam deposit. This presents a striking parallel between their crustal-scale geotectonic environments, and places both in an Early to Middle Proterozoic orogenic setting.

The second significant finding is the recognition of potential igneous-hydrothermal mineralization in abundant showings that have been termed Manitoba iron-sulphide copper-graphite (ISCG) occurrences. Their strange skarn-like association and mineral assemblage, and potential association with IOCG systems, has been documented in this study. Most important, their similarity to some of the pyrrhotite-hosted ISCG deposits in Australia, India and Chile has been noted. The further unexpected association of one ISCG occurrence with olivine carbonatite is described here for the first time, and raises many additional intriguing questions.

Perhaps, the most important conclusion is that the Trans-Hudson Orogen of Manitoba is very prospective for a range of deposit types not previously considered. The difficulties associated with remoteness, lack of outcrop exposure, and high-grade metamorphism and deformation can be overcome with persistence and sustained effort.

Detailed, high-resolution, multiparameter airborne geophysical surveys, including magnetic, radiometric and electromagnetic parameters, are strongly recommended for selected areas of high potential within the Trans-Hudson Orogen, including the ISCG belt of the northern Kisseynew Domain and the Eden deformation corridor. Appropriately located, such surveys are likely to stimulate a new generation of exploration activity in the province. Such an impact has occurred in the southern Great Bear Magmatic Zone, NWT, following release

Table 13: Selected targets for follow-up IOCG investigation, NTS 63K (Cormorant Lake).

ID #	Priority	Location	Surface geology	Mag (gamma)	eK (%)	eTh (ppm)	eU/eTh	Notes
1-S	1	NW Flin Flon	Metasandstone with peripheral basalt	Weak	1.2-1.4	3.0-4.0	0.2-0.25	
2-G	2	E Florence Lake	Domal structure, granite-granodiorite core rimmed by gabbro	Negative	1.6-1.8	4.0-5.0	0.25-0.30	Mag high on northern edge of dome
3-G	3	Anvil Lake Pluton	Granite & quartz diorite separated by fault	Strong	1.4-1.6	2.0-3.0	0.3-0.35	

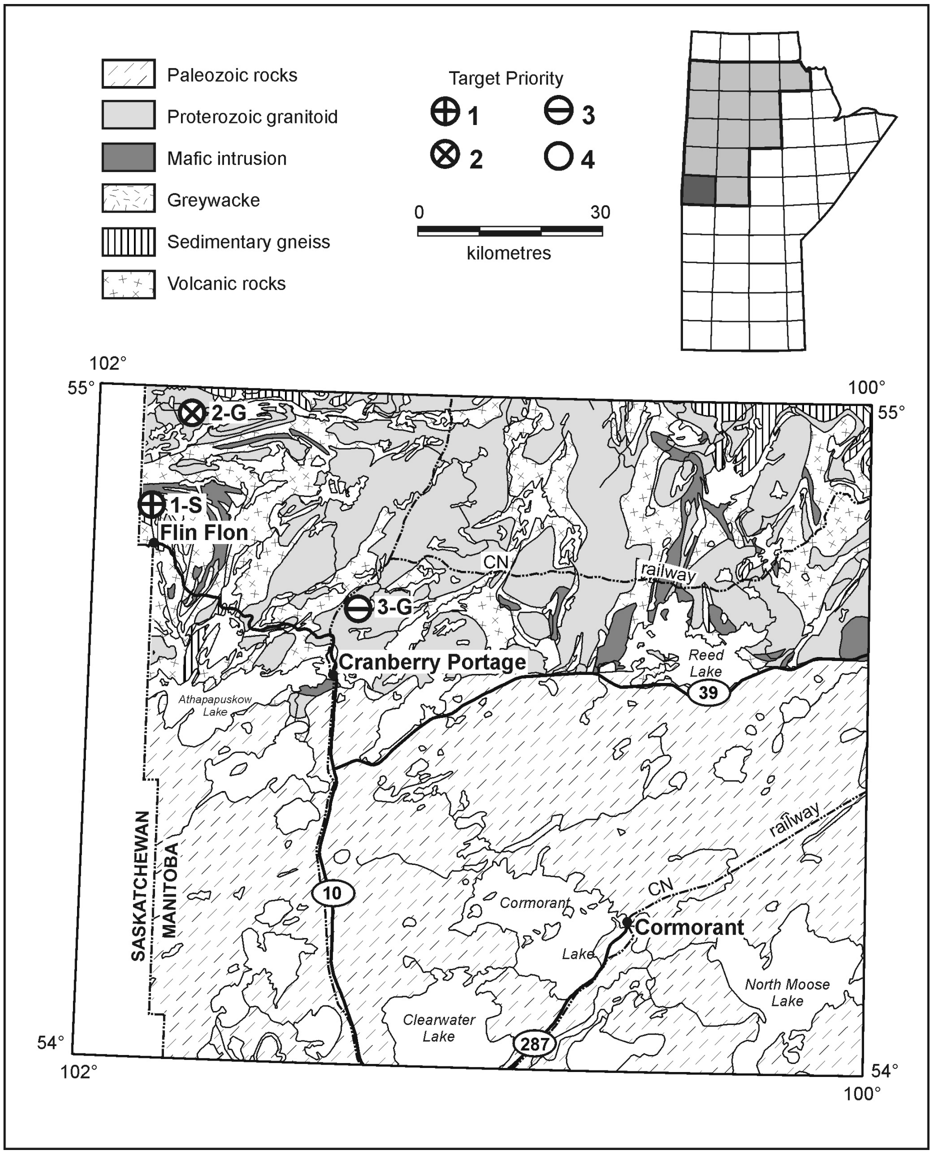

Figure 14: Selected targets for follow-up IOCG investigation, NTS 63K (Cormorant Lake).

of multiparameter, high-resolution airborne geophysical surveys carried out by the Geological Survey of Canada in 1994 (Charbonneau et al., 1994; Hetu et al., 1994; Goad et al., 2000a, b). Follow-up intensive exploration led to the discovery of the NICO Au-Co-Bi-Cu-Fe deposit near Lou Lake, which was undergoing a full bankable economic feasibility study by Fortune Minerals Limited in September 2004 (Fortune Minerals Limited, 2004).

Full-sequence exploration, combining multiparameter geophysical surveys, systematic and detailed field geology, and geochemical screening of geophysical targets, has the potential to generate many interesting discoveries in the Trans-Hudson Orogen.

Table 14: Selected targets for follow-up IOCG investigation, NTS 63J (Wekusko Lake).

ID #	Priority	Location	Surface geology	Mag (gamma)	eK (%)	eTh (ppm)	eU/eTh	Notes
1-X/S	1	NE Dion Lake	Magnetiferous pegmatite, basalt, amphibolite intruding metasandstone (migmatite)	None (strong mags E & W of pegmatite)	0.8-1.0	4.0-5.0	0.25-0.30	Assesment Files: 91387, 90606, 90605 indicate mineralized iron formation and tuffs
1-X/S/V	1	Dion Lake area	Circular outcrop feature: mafic volcanic core, peripheral carbonate, magnetiferous pegmatite, amphibole, quartz porphyry, all intruding metasandstone	Weak	1.2-1.4	5.0-6.0	0.3-0.35	Mag anomaly coincides with pegmatite

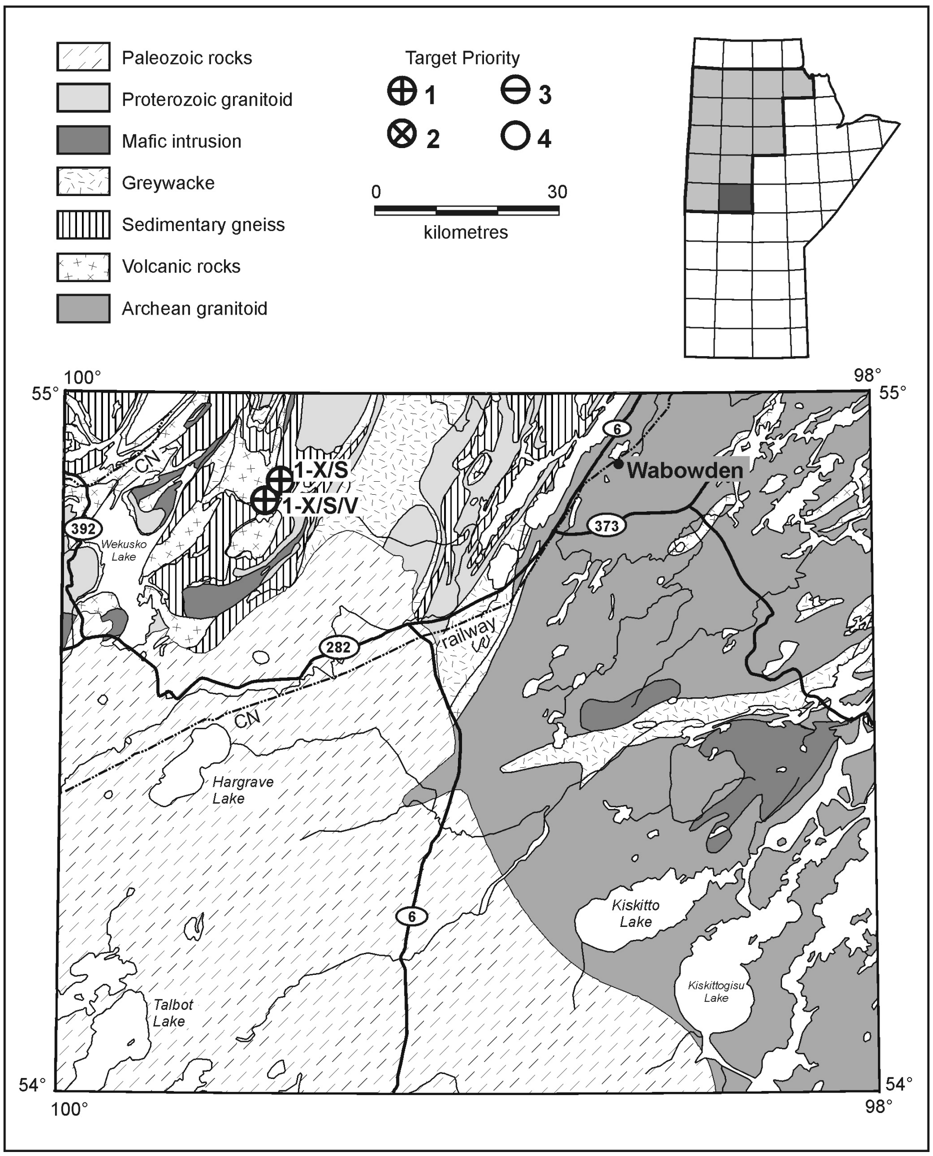

Figure 15: *Selected targets for follow-up IOCG investigation, NTS 63J (Wekusko Lake).*

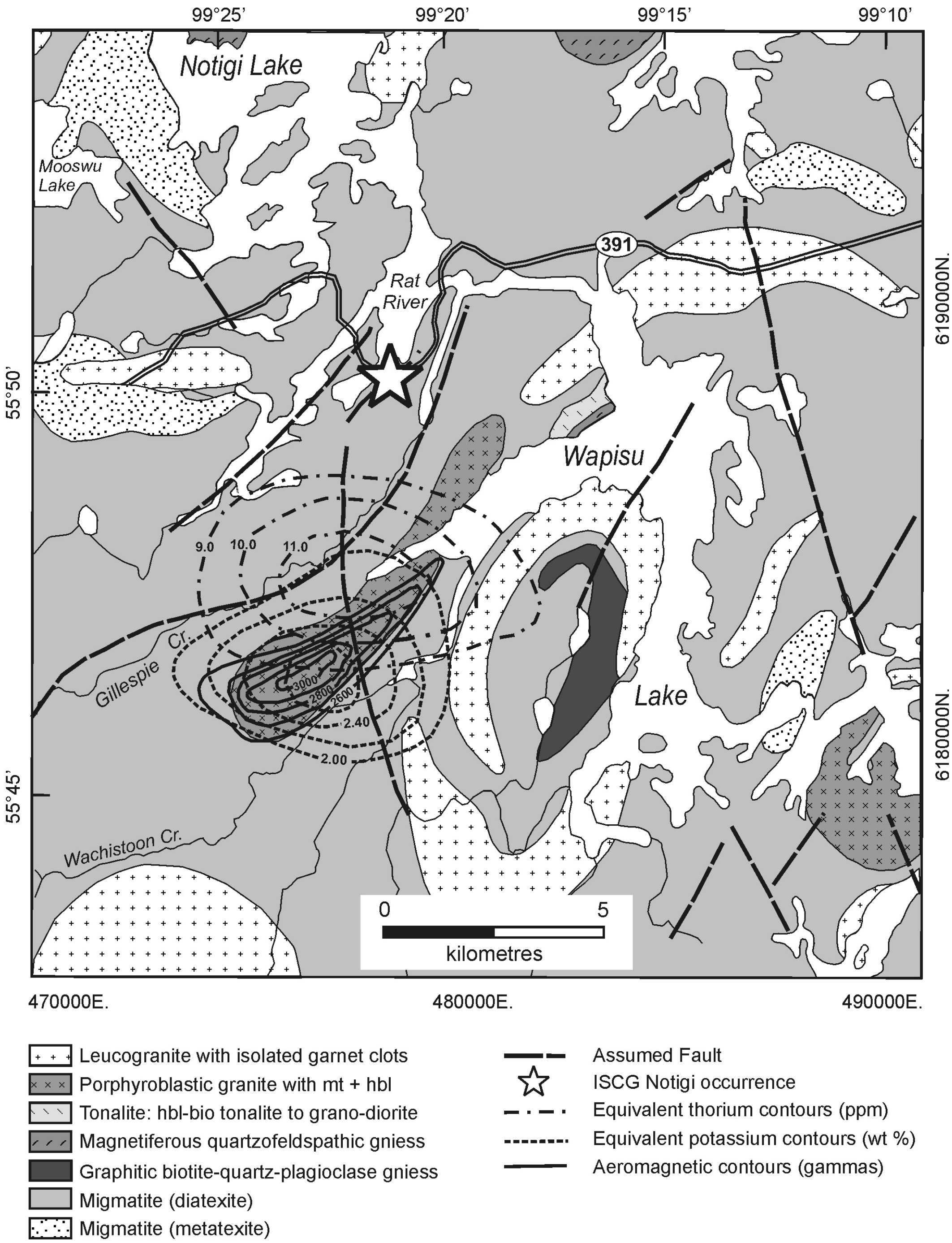

***Figure 16:** Regional geology with coincident radiometric and magnetic contours associated with the Wapisu Lake anomaly, NTS 63O (Nelson House); geology modified from Manitoba Energy and Mines (1989).*

Economic considerations

Recognition of several types of IOCG-related and igneous-hydrothermal types of mineralization opens the Trans-Hudson Orogen to exploration for deposit types not previously considered. Equally important, the Trans-Hudson Orogen comprises an amalgamation of various Proterozoic geotectonic terranes that are highly prospective for these deposits over vast and essentially unexplored regions (*see also* Mumin and Corriveau, 2004).

Deposits of the IOCG and ISCG types are attractive modern mining prospects because of their potential polymetallic nature and giant size and value. Continued provision of geoscience to establish a framework for IOCG exploration in the Trans-Hudson Orogen, and encouragement for prospectors and companies to search for these deposits, could generate major economic benefits for the province. The results of the present study demonstrate a methodology whereby vast terrains can be effectively 'scoped out' for the possible presence of IOCG and other igneous-hydrothermal styles of mineralization.

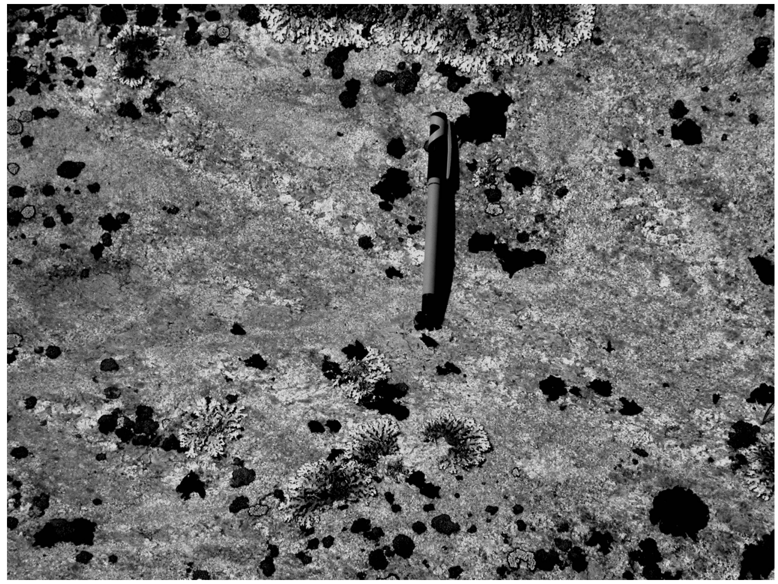

Figure 17: *Potassic-altered clasts in breccia of unknown origins, Wapisu Lake district, NTS 63O (Nelson House).*

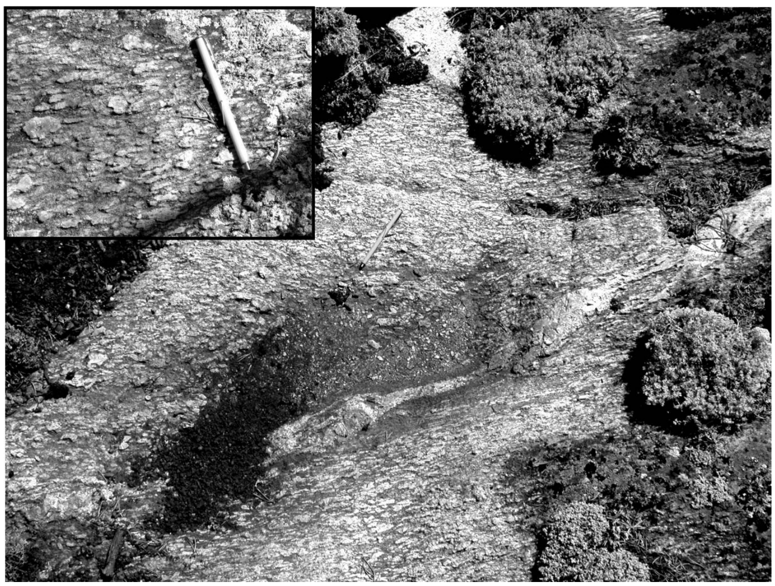

Figure 18: *Potassium feldspar embedded in magnetite-rich silicate matrix, Wapisu Lake district, NTS 63O (Nelson House).*

Figure 19: *Late structural breccia rich in hydrothermal sulphides, Notigi iron-sulphide copper-graphite occurrence, NTS 63O (Nelson House); field of view approximately 7 m.*

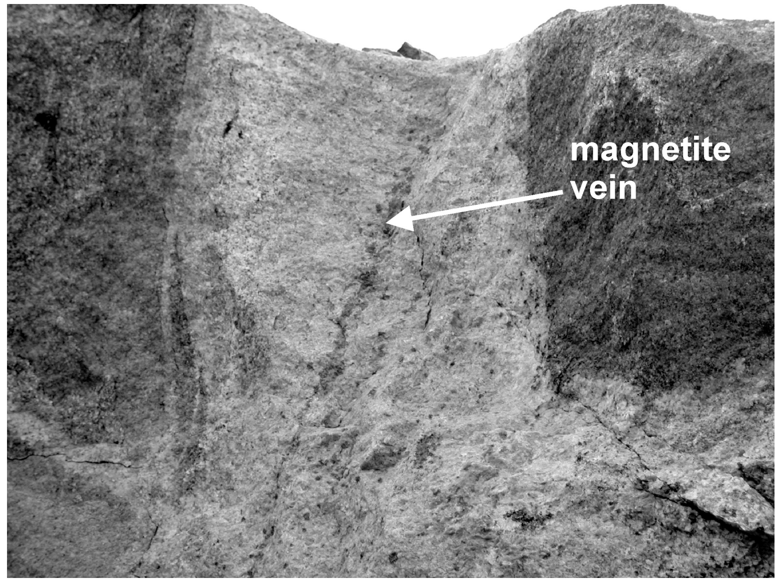

Figure 20: *Potassic granite with magnetite vein intruding granodiorite, road to South Indian Lake, NTS 64B (Uhlman Lake); width of granite dike approximately 1 m.*

Figure 21: *Young, unmetamorphosed, medium- to coarse-grained phaneritic granite, east of South Indian Lake and west of Cousins Lake, NTS 64B (Uhlman Lake).*

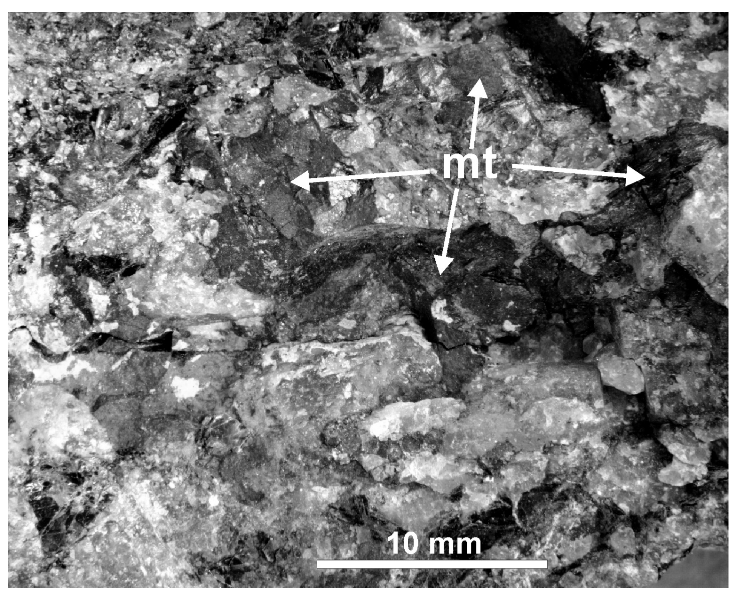

Figure 22: *Stereophoto of magnetite (mt) in medium-grained Black Trout diorite, Suwannee Lake, NTS 64B (Uhlman Lake); field of view is 32 mm.*

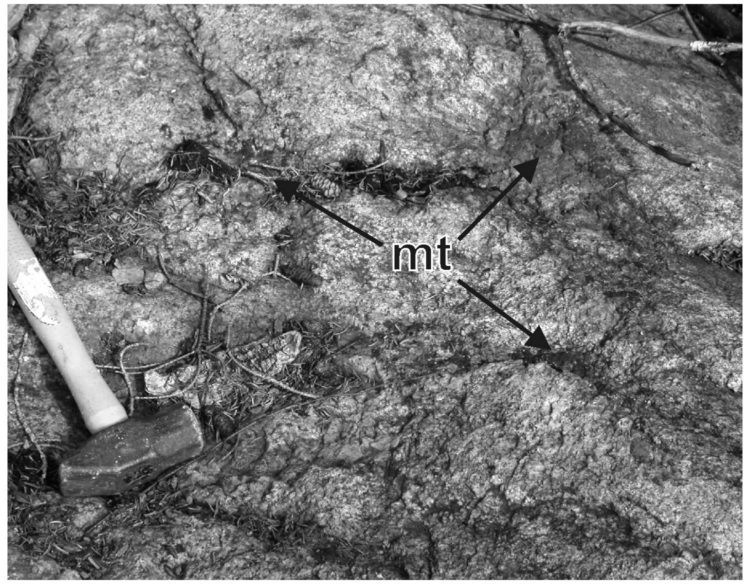

Figure 23: *Hematitic, reddish, altered granite-monzonite with up to 15% magnetite (mt), Suwanee Lake, NTS 64B (Uhlman Lake).*

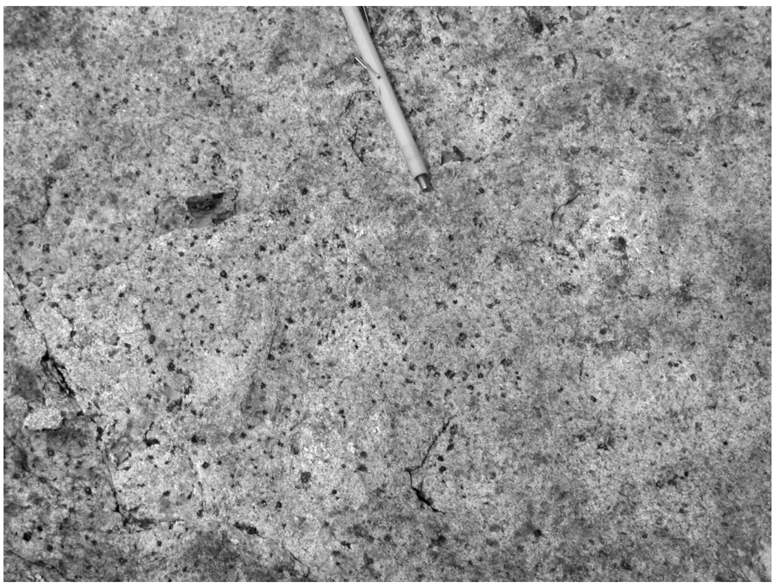

Figure 24: *Altered, pitted syenite intrusion, Foot Lake Complex, NTS 64B (Uhlman Lake). Abbreviation: mt, magnetite.*

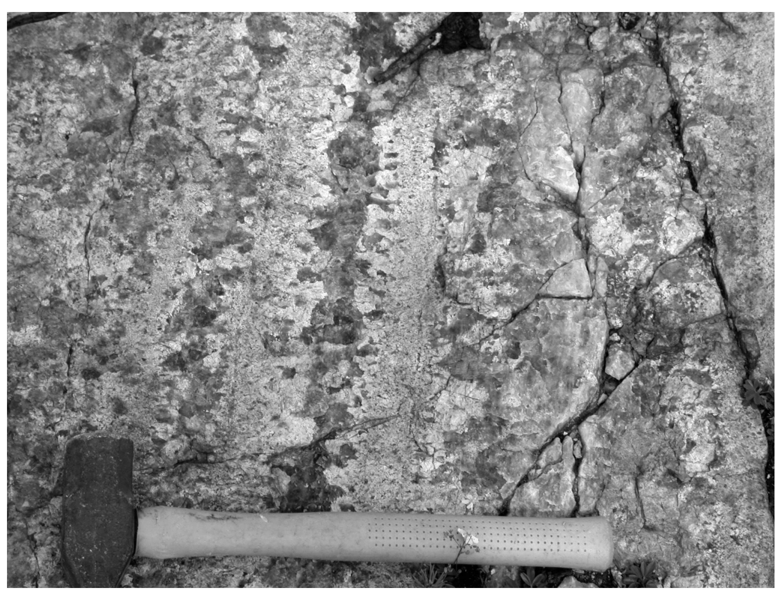

Figure 25: *Rhythmically banded quartz+two-feldspar pegmatite dike, Foot Lake Complex, NTS 64B (Uhlman Lake).*

Figure 26: *Sodium-rich plagioclase porphyry with epidote and pyrite alteration, Italy Bay, NTS 64B (Uhlman Lake).*

Figure 27: *Contact between igneous felsite and overlying banded volcanic-volcaniclastic rocks, Opachuanau supracrustal sequence, Italy Bay, NTS 64B (Uhlman Lake).*

Figure 28: *Semimassive Fe-sulphide–graphite occurrence with trace chalcopyrite, Rat Lake region, NTS 64B (Uhlman Lake).*

Figure 29: *Partially pegmatitic and moderately potassic granodiorite, Central Granville Complex, NTS 64B (Uhlman Lake).*

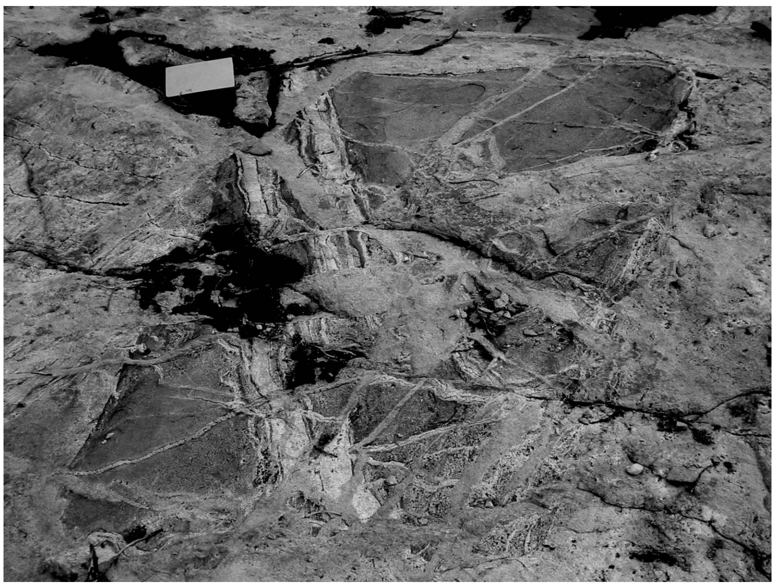

Figure 30: *Early mafic rocks intruded by syenite-aplite stockwork, Eden Lake, NTS 64C (Granville Lake); field book is 19 cm long.*

Figure 31: *Large mass of carbonatite from trench 1 at Eden Lake, NTS 64C (Granville Lake), showing weathered surface: 1) coarse-grained Sr-calcite carbonatite, 2) syenite with clinopyroxene–potassium feldspar–fenite alteration assemblage, 3) semimassive apatite vein, 4) clinopyroxene, and 5) potassium feldspar crystals.*

Figure 32: *High-grade hydrothermal rare earth element (REE) veins, comprising allanite, britholite, apatite, pyroxene, plagioclase, fluorite, calcite and titanite, invading syenite country rock, Eden Lake, NTS 64C (Granville Lake).*

Figure 33: *Structural brecciation of the Km 54 ISCG showing, NTS 64C (Granville Lake), with pyrrhotite-graphite±chalcopyrite mineralization in fractures; photo taken just west of Figure 34; rockcut is approximately 3 m high.*

Figure 34: *Domal jointing of aplite intrusions with hydrothermal pyrrhotite-graphite, pyroxene, carbonate, quartz ± chalcopyrite mineralization along flat-lying joints, Km-54 occurrence, about 54 km west of Thompson along Highway 391.*

Figure 35: Polished slab showing massive pyrrhotite-rich ISCG mineralization with abundant graphite+quartz, Notigi ISCG occurrence, Nelson House district; field of view 8 cm; see *Figure 36 for close-up.*

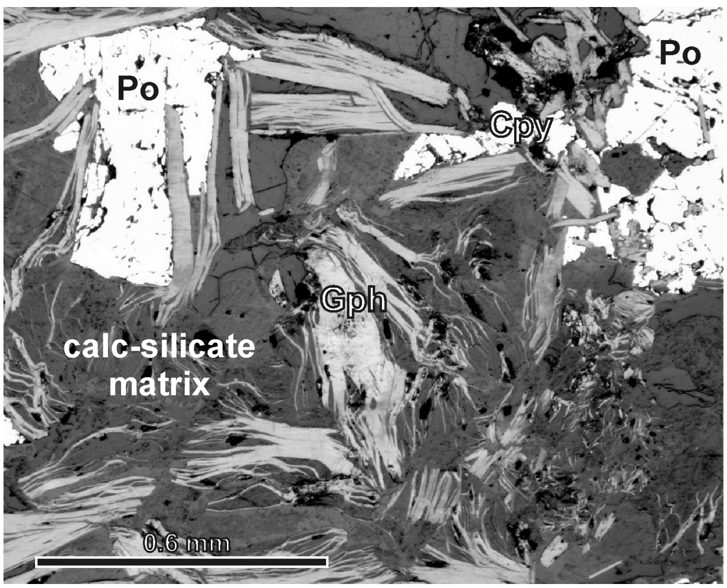

Figure 36: Photomicrograph of sample in Figure 35, taken in plane-polarized reflected light, showing graphite flakes (Gph) intergrown with pyrrhotite (Po), quartz, calcite, biotite and minor chalcopyrite; field of view 1.7 mm.

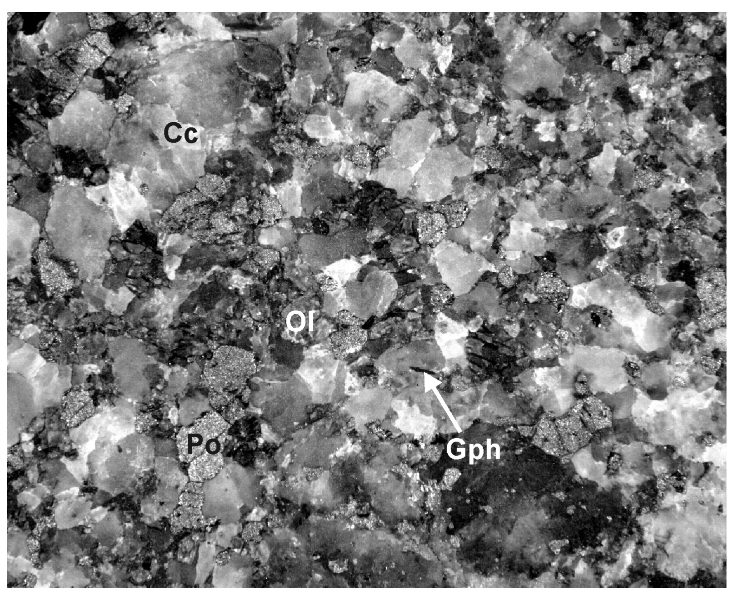

Figure 37: Stereophotograph of polished slab of material resembling olivine carbonatite, Notigi-1 quarry; field of view is 1.7 cm.

Figure 38: *Young granite-aplite-intermediate intrusive stockwork into arkosic metasedimentary rocks, approximately 75 km southeast of Leaf Rapids.*

Figure 39: *Gossanous Fe-oxide staining associated with igneous stockwork veining, 75 km southeast of Leaf Rapids.*

Figure 40: *Surface gossan of the Cu-quarry ISCG showing, approximately 85 km southeast of Leaf Rapids hosted in structurally sheared, biotite-garnet gneiss of the northern Kisseynew Domain.*

Figure 41: *Megacrystic, mica-rich, hematitic and locally sulphidic granite near the Cu-quarry showing, approximately 85 km southeast of Leaf Rapids.*

Figure 42: *Granitic dike grading to quartz vein and sulphidic selvage, Highway 391, east of Nelson House.*

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