THE SAWYER LAKE IRON-ORE DEPOSIT, WESTERN LABRADOR: POTENTIAL FOR FUTURE HIGH-GRADE IRON-ORE DEPOSITS IN THE LABRADOR TROUGH

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ABSTRACT

The Sawyer Lake deposit, ca. 65 km southwest of Schefferville, is a new type of high-grade iron that differs markedly from other deposits in the northern Labrador Trough. The deposit was initially discovered in the 1930s and sporadic exploration since then has defined a significant iron-ore resource with up to 12 million tones of high-grade iron ore (>60% Fe). The main ore zone at the Sawyer Lake deposit is located in the lower Sokoman Formation, below a thick sequence of volcanic rocks of the Nimish Formation. The deposit forms a stratiform orebody, has a saddle-reef morphology and consists of hard, massive to weakly banded high-grade hematite, containing >90% fine-grained, microplaty hematite and minor microgranular quartz. The hard hematite ore is commonly brecciated, and has angular fragments of hematite in a quartz–hematite matrix. Brecciation is associated with the collapse of hematite into open spaces created by the leaching of silica. The high-grade hematite body is surrounded by oxidized iron formation consisting of alternating hematite and cherty bands, and abundant evidence for the remobilization of hematite and quartz, and secondary hematite enrichment.

In contrast to high-grade direct-shipping ore deposits in the Schefferville area, no evidence of supergene enrichment has been recorded at the Sawyer Lake deposit, and syndiagenetic iron enrichment is also considered unlikely. Macroscopic and petrographic studies and comparisons with other high-grade hematite deposits worldwide, indicate that enrichment is related to hypogene processes, in which hydrothermal fluids leached silica and precipitated secondary hematite. Although the source of hydrothermal fluids is unknown, they may be related to dewatering of underlying shales during the Hudsonian orogeny or circulation of basinal brines during regional-scale thrusting.

INTRODUCTION

OVERVIEW

The Sawyer Lake iron-ore deposit is located in northwestern Labrador, approximately 65 km southwest of Schefferville (NTS map area 23I/05; Figure 1). Access to the area is via helicopter only, as there is no road access. The Sawyer Lake deposit consists of an irregularly shaped body of high-grade (>60% Fe) hard blue hematite, which defines the top of a small hill ~1.5 km west of Sawyer Lake (Plate 1). It was discovered in 1937, and exploration over the past 70 years has recognized that it is a distinct deposit type, markedly different from the soft high-grade direct-shipping ore (DSO) deposits of the Schefferville area.

This contribution presents the results of initial field and petrographic studies of the Sawyer Lake deposit and surrounding altered iron formation. Fieldwork in 2012 and 2013 included a number of site visits and detailed logging of drillcore stored in Schefferville; these data have been combined with industry reports to develop a genetic model for iron-ore enrichment. During the past 15 years, many studies have investigated the origin of high-grade hematite-rich, iron-ore deposits (e.g., Barley et al., 1999; Taylor et al., 2001; Gutzmer et al., 2006, 2008; Lascelles, 2007; Rosière et al., 2008; Angerer and Hagemann, 2010; Ramanaidou and Morris, 2010; Lascelles, 2012); the results from these studies will be compared with the characteristics of the Sawyer Lake deposit. The implications of these comparisons for regional exploration in the Labrador Trough will be discussed, and other aspects of ongoing research will be briefly outlined.

REGIONAL GEOLOGY

The Sawyer Lake deposit lies within the geological belt known as the Labrador Trough. The Labrador Trough consists of Paleoproterozoic (2.17 to 1.87 Ga; Rohon et al., 1993; Findlay et al., 1995; Machado et al., 1997) sedimentary and volcanic rocks, collectively known as the Kaniapiskau Supergroup (Zajac, 1974; Wardle and Bailey,
The trough extends for more than 1100 km from the northwest corner of Ungava Bay south to Lake Pletpi (Clark and Wares, 2005), and it forms the western part of the larger New Québec orogenic belt. This records the oblique convergence and collision of the Archean Superior Craton to the west and an Archean core zone to the east at 1.82 to 1.77 Ga (Wardle et al., 1990, 2002).

The Kaniapiskau Supergroup is subdivided into three sedimentary and volcanic cycles deposited during the development of a foreland basin (Zajac, 1974; Wardle and Bailey, 1981; Le Gallais and Lavoie, 1982; Clark and Wares, 2005). Cycle 1 (the lower cycle) consists of a continental-rift basin overlain by passive margin sedimentary rocks that developed during rifting on the eastern margin of the Superior Craton at least 2.17 Ga ago (Rohon et al., 1993). The immature sandstones and siltstones of the Seaward Formation were deposited in a fluvial to intertidal system, and grade upward into the passive margin sediments of the Attikamagen Group. The Attikamagen Group includes Attikamagen Formation siltstone and shale, Denault Formation dolomite, Fleming Formation chert breccia and Dolly Formation shale and siltstone.

Cycle 2 is a transgressive sequence that progresses from shelf-type rocks (Wishart Formation sandstone and siltstones, and Sokoman Formation iron formation) at the base to deeper water turbidites of the Menihek Formation at the
The intermediate to mafic volcanic rocks of the Nimish Formation are interbedded with the Sokoman Formation in the Dyke Lake area (Evans, 1978). In addition, the Wishart and Sokoman formations are intruded by a number of pre-tectonic gabbro sills, which may relate to the Nimish volcanism or later volcanic events (Evans, 1978; Watanabe, 1996). A syenite cobble from a polymictic conglomerate in the Nimish Formation yielded a U–Pb age of 1877.8 ± 1.3 Ma, which was interpreted as an approximate age for the coeval Sokoman Formation (Findlay et al., 1995). In places, Cycle 2 is unconformably overlain by Cycle 3 arkoses, which are interpreted as a synorogenic molasse. During the collision of the Superior Craton with the core zone in the Hudsonian Orogen (1.82 to 1.77 Ga), the Kaniapiakau Supergroup was folded and thrust westward over the Archean basement rocks (Wardle et al., 1990, 2002).

The iron-ore deposits in the Labrador Trough are hosted in the Sokoman Formation, a 30- to 170-m-thick sequence of cherty iron-rich sedimentary rocks. The general stratigraphy of the Sokoman Formation is based on mapping around Schefferville (Zajac, 1974), and can be correlated throughout the Labrador Trough. The base of the Sokoman Formation is marked by a dark-green to black ferruginous shale and minor tuffs, sometimes called the Ruth formation (Zajac, 1974). Above this, the Sokoman Formation consists of three units. The lower unit (Lower Iron Formation) consists mostly of a carbonate–silicate facies with some magnetite. This grades upward into the Middle Iron Formation, an oxide facies with abundant coarse-grained hematite and/or magnetite and sugary-textured quartz. These oxide-rich beds are the most important, economically, and where the iron-rich layers and lenses commonly contain more than 50% hematite and magnetite. The upper part of the Sokoman Formation (Upper Iron Formation) is a carbonate–silicate facies with minor oxides.

PREVIOUS WORK AND HISTORY OF EXPLORATION

The occurrence of high-grade iron-ore deposits in the vicinity of Sawyer Lake was first reported in 1937 by Mathiau Andre, a Montagnais Innu guide, who brought a sample of high-grade hematite ore to the attention of Dr. Joseph Retty, chief geologist of Labrador Mining and Exploration Company (LME). Exploration activity by LME through the 1930s and 1940s included detailed field mapping, test pitting, trenching and sampling (Retty, 1938, 1939; Retty and Moss, 1945; Dufresne, 1950). In 1944, five drillholes (total 238 m) were completed on the property, with the deepest hole ending in high-grade ore at 61 m (Retty and Moss, 1945). Additional diamond drilling was carried out in 1949, with five drillholes on the main deposit (total 162 m) and an extensive program of test drilling in the surrounding area (60 short drillholes, total 650 m; Retty, 1950). Although this work identified a significant iron-ore resource at Sawyer Lake, no other nearby deposits were discovered, and LME focused their activities after 1949 on developing the large iron-ore deposits farther north in the Knob Lake area.

 Exploration activity at Sawyer Lake from 1949 to the 1980s was restricted to regional government mapping and a number of short visits by company geologists (Price, 1979; Wardle, 1979). Bulk sampling and metallurgical test work in the late 1980s showed that lump ore (6–25 mm) from Sawyer Lake could successfully produce direct reduced iron (Bowie and Lepinski, 1989), and airborne VLF and magnetometer surveys were completed over the deposit in 1995 (Scott, 1996). In the 2000s, renewed exploration activity at the Sawyer Lake deposit included prospecting, mapping and trenching (Chavez et al., 2005). Based on these results, Labrador Iron Mines commenced a diamond-drilling program in 2008, drilling nine drillholes having a cumulative length of 539.5 m (Vatcher et al., 2009). All the drillholes encountered high-grade (>60% Fe) ore having a maximum thickness of 41.4 m (@ 67.9% Fe), and two holes terminating in ore.

The Sawyer Lake deposit does not have a NI-43-101 compliant mineral-resource calculation and estimates by LME and IOC geologists vary greatly, from 3 to 16 million tonnes, depending on assumptions regarding the size and density of the deposit. In 1998, Fenton Scott compiled all historical data from the Sawyer Lake deposit in an attempt to create an ore-reserve calculation (Scott, 1998). This resulted in a non-NI-43-101 compliant probable mineable reserve of 5.87 million tonnes (66% Fe), in addition to indicated and inferred resources of 2.32 and 3.8 million tonnes, respectively. However, care must be taken with these estimates, as they may overestimate the depth of mineralization and include areas of mineralization that are too narrow to be mined economically (Chavez et al., 2005). Based on results of the 2008 drilling program, the Sawyer Lake deposit also has potential for expansion at depth and along strike.

SAWYER LAKE IRON-ORE DEPOSIT

LOCAL GEOLOGY

The stratigraphy in the vicinity of the Sawyer Lake deposit consists of sedimentary and volcanic rocks of the Kaniapiakau Supergroup (Figure 2; Dufresne, 1950; Evans, 1978; Wardle, 1979). The oldest exposed rocks are grey shales and siltstones of the Dolly Formation, which are overlain by orthoquartzites and siltstones of the Wishart Formation. The Wishart Formation is intruded by gabbro sills, which may be related to the overlying Nimish Formation (Evans, 1978). The lowest iron-bearing rocks are black
ferruginous shales and minor tuffs that correlate to the Ruth formation in the Schefferville area (Dufresne, 1950; Wardle, 1979). These are not exposed in the study area, but have been recorded beneath altered iron formation in recent exploration drilling ~4 km northwest of the Sawyer Lake deposit.

The stratigraphy of the Sokoman Formation proper differs from the typical sequence described in the Schefferville area. The Middle Iron Formation is not recorded, and the Lower and Upper Iron formations are separated by a thick sequence of Nimish Formation volcanic rocks (Wardle, 1979). The Sawyer Lake deposit is hosted in the Lower Iron Formation, which consists of green- to grey-laminated silicate chert with disseminated and thin bands of magnetite. Close to the deposit this chert has been extensively altered and oxidized. The Nimish Formation volcanic rocks consist predominantly of green to grey, vesicular and plagioclase phytic basalts, interbedded with lesser conglomerates containing rounded clasts of lava and jasper (Wardle, 1979). The lavas are overlain by ferruginous tuffs and chert, which Wardle (1979) interpreted as a transition zone between waning Nimish volcanism and deposition of the thinly bedded Upper Iron Formation.

### PETROGRAPHY

The Sawyer Lake deposit is subdivided into two main rock types, which are readily differentiated based on their mineralogical and physical characteristics. The core of the ore body consists of a lens of hard, high-grade hematite (>60% Fe), surrounded by pink oxidized iron formation. These units are interpreted as oxidized equivalents of the Lower Iron Formation, although the contact between the oxidized iron formation and unaltered iron formation was not observed.
High-Grade Hematite Ore

High-grade hematite is the dominant ore horizon in the Sawyer Lake deposit. It is a characteristic dark-grey/blue, and has a metallic lustre; it has been described by previous authors as a ‘steel-rail hematite’ due to its appearance in glacially polished outcrops (I.S. Zajac, personal communication, 2013). It is subdivided into two broad classes, based on macroscopic characteristics.

Most of the ore consists of massive hematite ore (Plate 2A, B). In places, this unit displays traces of banding, defined by more quartz-rich layers, or variations in porosity from 0 to 20%. These bandings/laminations reflect replacement of original textures in the unaltered iron formation, with the more quartz-rich and porous layers representing chert-rich bands. The massive hematite ore consists of almost pure hematite (>60% Fe), minor quartz and remnant magnetite. Hematite is very fine grained (<10 μm) and can be defined as microplaty hematite (Plate 3A). This microplaty hematite is thought to have originated through the oxidation of magnetite (martization) and secondary precipitation in pore spaces. No evidence of magnetite was found during petrographic examination but relatively high magnetic susceptibilities (up to 6 x10^-3 SI) indicate that some remnant magnetite remains. Microcrystalline quartz is a minor constituent of massive hematite ore, typically making up <10% of the total mineralogy. This quartz is inconspicuous in hand sample and forms small irregularly distributed patches surrounded by hematite. Close to the contact with the oxidized iron formation the proportion of quartz increases (up to 30%; Plate 3B), which represent primary quartz that was not replaced during the mineralizing event. Goethite is rare in high-grade hematite ore, and where observed, fills pore spaces, veins and vugs.

Brecciated high-grade hematite ore is found locally throughout the ore zone, and has been recorded in both outcrop and drillcore. These breccias consist of angular fragments of massive microplaty hematite cemented by hematite and quartz (Plate 2C, D). The degree of displacement and brecciation is highly variable, ranging from massive hematite broken up and crosscut by veins of hematite and quartz (crackle breccia; Plate 3C), to angular fragments of massive hematite in a quartz matrix (rubble breccia; Plate 3D). Breccias are also associated with open vugs lined by euhedral quartz. The presence of these breccias indicates that open space was created during or after the main mineralizing event, due to the dissolution of cherty layers. Some of the open pore spaces and vugs are filled by late-stage goethite (Plate 2C), most likely related to influxes of groundwater in geologically recent times.

Oxidized Iron Formation

Fine-grained, oxidized iron surrounds the lenses of high-grade hematite ore in the Sawyer Lake deposit. The contact between the oxidized iron and the ore lenses is generally gradational with an increase in iron content from ~30% Fe to >45% Fe. Occasionally, sharp contacts with the high-grade hematite ore have been observed, which crosscut bedding in the oxidized iron.

The oxidized iron formation consists of alternating hematite and cherty bands ranging in thickness from 1 to 20 mm (Plate 2E). Cherty beds are pink to off-white and consist predominantly of two main quartz generations, i.e., early microgranular quartz (<5 μm) with irregular boundaries and later recrystallized coarser grained quartz (>20 μm). Multiple generations of hematite have also been recorded. Fine-grained, dusty hematite is locally associated with microgranular quartz, giving the chert layers a distinctive pink colour (jasper). This has been recrystallized to euhedral to subhedral blades of hematite (<10 μm) that are disseminated throughout the chert (Plate 4A). Locally, these form bands and subrounded aggregates of microplaty hematite (Plate 2F), which reflect the secondary enrichment of hematite in the cherty layers. Close to the contact with the high-grade hematite ore, secondary hematite makes up >50% of the chert bands. Numerous veinlets of quartz and hematite crosscut the cherty bands (Plate 4A, B) and are commonly associated with aggregates of microplaty hematite. Rare pseudomorphs have also been recorded in cherty bands, with hematite and quartz replacing an unknown mineral (carbonate or magnetite?).

The hematite-rich bands consist of >80% microplaty hematite with lesser intergranular quartz (Plate 4C). These bands commonly have diffuse and irregular boundaries and are associated with local hematite enrichment in the adjacent chert bands. Although no magnetite or kenomagnetite (partially oxidized magnetite) have been recorded in thin section, some areas are weakly magnetic indicating some remnant magnetite has survived alteration and oxidization.

Porosity in the oxidized iron formation is generally low, with rare vugs and pores filled by quartz and hematite. Late-stage goethite is also recorded in pore spaces and fractures (forming comb structures) and occasionally forms fine disseminations in cherty bands (giving the core a yellow colour). Rare collapse breccias have also been recorded, with bands of hematite and chert broken up and cemented by late-stage quartz and hematite.
Plate 2. Photographs of representative rock types of the Sawyer Lake deposit. A) Outcrop of massive high-grade hematite ore; B) Massive high-grade hematite ore (DDH-SL-004A @ 34 m); C) Brecciated high-grade hematite ore and angular fragments of hematite in a matrix of hematite, quartz and late-stage goethite; D) Partially brecciated high-grade hematite ore (DDH-SL-007 @ 19.3 m); E) Banded oxidized iron formation (DDH-SL-007 @ 37.5 m); F) Subrounded aggregates of secondary hematite and quartz-lined vugs in oxidized iron formation (DDH-SL-007 @ 50.4 m).
The Sawyer Lake deposit is located in the southeastern sector of the Petitsikapau synclinorium (Wardle, 1979), a major regional structure that formed during the Hudsonian Orogen. In contrast to the generally north-northwest–south-southeast-trending, southeast-plunging folds elsewhere in the orogen, the southeastern sector of the Petitsikapau synclinorium has been rotated clockwise due to late-stage sinistral-slip movement on the Mina Lake Fault (Wardle, 1979). This has formed a series tight upright folds plunging to the northwest, with the Sawyer Lake deposit located in the trough of a major north-trending syncline (Figure 2).

Bedding in the Sawyer Lake deposit is defined by bands of chert and hard, blue hematite in the oxidized iron formation as well as by variations in porosity in the high-grade hematite ore. The porosity variations reflect primary bedding features that existed prior to enrichment. The strike of these beds varies across the deposit (Figure 3) and outlines a small north-plunging anticline on the eastern limb of the larger syncline (Figure 2). Although the contact between the high-grade hematite ore and oxidized iron formation locally crosscuts bedding, cross-sections through the orebody show that the high-grade hematite ore forms a stratiform body with a saddle reef-like structure that thins toward the centre of the deposit and follows bedding across the crest of the anticline (Figure 4). Petrographic examination of moderately enriched iron formation, close to the contact with the high-grade hematite ore, reveals preservation of small-scale folding of the iron formation, defined by hematite-rich and hematite-poor layers (Plate 4D). This indicates that the original textures of the iron formation were preserved during mineralization, or that enrichment predates at least one

**Plate 3. Photomicrographs of high-grade hematite ore in reflected light.** A) Massive microplaty hematite with well-developed porosity; B) Massive high-grade hematite ore close to contact with oxidized iron formation, with abundant microcrystalline quartz; C) Angular fragments of massive hematite crosscut by hematite and quartz veinlets (crackle breccia); D) Fragment of massive hematite engulfed by late-stage quartz and hematite (rubble breccia). $H_1$ - early massive microplaty hematite, $H_2$ - late hematite, $Q$ - quartz, $P$ - pore space.
phase of folding. No evidence of faulting was recorded during trenching at Sawyer Lake, but intervals of clay-like fault gouge were observed in drillcore. These small-scale faults could be important conduits for fluid flow through the deposit.

**DISCUSSION**

**GENESIS OF THE SAWYER LAKE DEPOSIT**

The hard, high-grade hematite ore at Sawyer Lake is very different from the ‘soft’ DSO deposits in the Schefferville area, which consist of friable high-grade (>55% Fe) material containing abundant secondary goethite. Previous work in the Schefferville area has attributed iron enrichment to deep supergene weathering during the Cretaceous, and leaching of primary silica and carbonates and precipitation of secondary iron oxides (Stubbins et al., 1961; Gross, 1968). In contrast, the Sawyer Lake deposit consists of hard hematite ore with little or no goethite. Where present, goethite is volumetrically minor, restricted to late-stage pores, veins and vuggy chert (partially leached), and is most likely related to recent groundwater circulation. In addition, high-grade hematite ore at Sawyer Lake retains evidence of primary textures and has a well-developed alteration halo (oxidized iron formation), which is not compatible with a model of supergene enrichment. Therefore, the genesis of the Sawyer Lake deposit is not related to supergene or supergene-modified hypogene enrichment.

Syndiagenetic models suggest that chert-free iron formations formed during diagenetic processes, and have been suggested for a number high-grade hematite ores where no
evidence of chert bands have been recorded (Lascelles, 2007, 2012). However, the presence of highly porous bands and dissolution breccias at Sawyer Lake clearly show the leaching of chert beds and a wholly syndiagenetic model is also considered unlikely.

Based on this study, it is likely that iron enrichment at Sawyer Lake is related to hypogene processes, as was first suggested for the deposit by Gross (1968). In recent years, hypogene processes have been increasingly recognized as important in the formation of high-grade hematite deposits, particularly in Australia, Brazil, and South Africa (e.g., Barley et al., 1999; Taylor et al., 2001; Netshiozwi, 2002; Harding, 2004; Rosière et al., 2008; Angerer and Hagemann, 2010). The Sawyer Lake deposit shares several key characteristics with some of these deposits, notably the massive to brecciated high-grade hematite ores at the Thabazimbi and Zeekoebaart deposits in South Africa (Netshiozwi, 2002; Harding, 2004). Models of hypogene-related iron enrichment involve the circulation of hydrothermal fluids after diagenesis, in which fluids are concentrated in areas of structural deformation that facilitate increased fluid flow.

Figure 3. Geological map of the Sawyer Lake deposit showing the distribution of outcrops, trenches and location of drillholes. Adapted from Retty and Moss (1945), Chavez et al. (2005) and Vatcher et al. (2009).
As these oxidizing fluids circulate through the iron formation, they transform magnetite to hematite (liberating Fe²⁺; Ohmoto, 2003) and form distinctive alteration zones around orebodies (Lobato et al., 2008). At the Thabazimbi and Zeekoebaart deposits, a distal alteration zone consists of bands of partially leached chert and secondary hematite (Netshiozwi, 2002; Harding, 2004; Lobato et al., 2008).

Figure 4. Schematic east–west (A-B) and north–south (C-D) cross-sections through the Sawyer Lake deposit showing the saddle-reef morphology of the deposit. For location of the sections refer to Figure 3.
which is very similar to the oxidized iron formation surrounding the orebody at Sawyer Lake. This alteration zone formed where oxidizing fluids transformed magnetite, Fe silicates and carbonates in the unaltered iron formation into hematite and chert. Iron and silica were remobilized by these fluids, as shown by the abundant hematite and quartz veinlets. Precipitation of secondary hematite is suggested by the association of hematite with secondary quartz and aggregates of secondary, microplaty hematite in the chert-rich bands. Minor leaching of chert and/or volume loss also increased porosity in the oxidized iron formation, which would have facilitated further fluid circulation.

The high-grade hematite ore at Sawyer Lake represents the zone of most intense hydrothermal alteration. Quartz in the chert-rich bands has been completely leached and replaced by microplaty hematite. Variations in porosity in the massive ores reflect the original bedding, with the higher porosity bands replacing former cherty layers. Dissolution of silica also generated open space in the high-grade hematite ore, which was reduced by collapse (forming breccia zones) and precipitation of secondary quartz and hematite in open pore spaces.

The source of the hydrothermal fluids at Sawyer Lake remains enigmatic. The only possible source of magmatic fluids is a series of gabbro sills that intrude the Sokoman and Wishart formations, which are either related to the underlying Nimish Formation volcanic rocks or the Montagnais Intrusive Suite (Evans, 1978). However, these gabbroic magmas were essentially dry and are not likely to have been the source of significant fluids. Although the heat anomalies associated with the intrusion of these sills may have resulted in the formation of hydrothermal convection cells in the Sokoman Formation, their emplacement predate folding and deformation of the Kaniapiskau Supergroup, which is necessary to create the hydraulic conductivity necessary for significant fluid flow. In addition, these sills are extensively altered, with olivine pseudomorphed by serpentine, chlorite and tafel and clinopyroxene variably altered to tremolite and actinolite (Watanabe, 1996). Similar alteration of dykes spatially associated with hypogene hematite deposits have been noted in Brazil, Australia and South Africa (Lobato et al., 2008) and indicates that these sills intruded the Kaniapiskau Supergroup prior to hydrothermal alteration.

An alternative source of the hydrothermal fluids is connate waters sourced in the underlying shales of the Ruth and Wishart formations, which was first suggested by Gross (1968). During the Hudsonian Orogeny, compaction of the shales would have resulted in dewatering and tectonic pumping of fluids through the relatively permeable Sokoman Formation, with the impermeable Nimish Formation acting as a barrier to upward fluid flow. Fluids may also be related to the circulation of basinal brines during regional-scale folding or thrusting, which has been suggested for a number of other hypogene hematite deposits, e.g. Mount Tom Price, Australia (Thorne et al., 2004). In some respects, these models are analogous to those proposed for Mississippi Valley-Type (MVT) Pb–Zn deposits.

**REGIONAL IMPLICATIONS**

Exploration activities around the Sawyer Lake deposit have recognized the potential for discovery of similar high-grade hematite deposits. Localized iron enrichment in the Stewart Lake area (~5 km north-northeast of Sawyer Lake) was reported by Griffis et al. (1944). Recent drilling by Mamba Minerals Limited at the nearby CLC deposit (Figure 1) has shown that iron enrichment continues along strike from the Sawyer Lake deposit to the Stewart Lake area, with intersections of 101 m averaging 52% Fe and high-grade intervals of 63 and 65% Fe (Mamba Minerals Limited, press release, May 3rd 2013). Similar iron enrichment has been described from the Astray Lake deposit (Figure 1), with blue hematite replacing leached jasper, and abundant brecciated high-grade ore located below the Nimish Formation (Gross, 1968). In addition, several other high-grade hematite deposits display characteristics intermediate between those of the classic supergene deposits described by Stubbins et al. (1961) from the Schefferville area and those of the hard, high-grade hematite deposit at Sawyer Lake. The Houston and Malcolm deposits, located southeast of Schefferville (Figure 1), consist of areas of massive hard blue hematite similar to the Sawyer Lake deposit that grade into more friable ore with secondary goethite and pyrolusite. Oxidized iron formation is recorded close to these deposits and displays abundant evidence of secondary hematite enrichment. Similar alteration has also been recorded close to other high-grade hematite deposits previously considered to be purely supergene in origin (e.g., Joyce Lake deposit; Figure 1). These deposits may have formed during supergene overprint of an early hypogene enrichment event, similar to the Thabazimbi deposit in South Africa (Netshiozwi, 2002). However, further geochemical and isotopic analyses are needed to determine an appropriate genetic model for these deposits.

A hypogene model for high-grade hematite enrichment in these deposits has important implications for future exploration activities in the Labrador Trough, particularly when combined with airborne magnetic and gravity studies. Previous exploration models based on the soft DSO ore deposits in the Schefferville area have focused on areas of potential supergene enrichments, preferentially located in synclinal depressions and/or down-faulted blocks. In contrast, deposits similar to Sawyer Lake may be blind orebodies that are not related to the current land surface. Structures
such as isoclinal folds and fault zones are important in concentrating fluid flow, particularly below relatively impermeable units such as the Nimish Formation volcanic rocks. Zones of hydrothermal alteration, including oxidation and partial leaching of the iron formation and alteration of pre-tectonic gabbro sills may be used as vectors toward iron mineralization. Secondary goethite enrichment may reflect recent groundwater flow and is common even in areas with no evidence of economic iron enrichment (Dufresne, 1950; Wardle, 1979). Therefore, the presence of goethite is not considered a good indicator of the presence of high-grade deposits.

FUTURE WORK

This research is focused on the determining the origin of high-grade hematite ore deposits in the Labrador Trough, including hard hematite ores similar to the Sawyer Lake deposit, soft DSO deposits of the Schefferville area and intermediate ore deposits (e.g., Houston and Malcolm deposits). These studies include detailed field-based and petrographic studies of these deposits, as well as rare-earth element geochemistry and oxygen isotope studies. Such techniques have been shown to be able to differentiate between supergene and hypogene iron-ore enrichment (Gutzmer et al., 2006, 2008) and will be important in developing new exploration models in the Labrador Trough.

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