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Mineral chemistry and supporting databases for TGI4 project on "Trace elements in Fe-oxides from fertile and barren igneous complexes: Investigating their use as a vectoring tool in the intrusions that host Ni-Cu-PGE deposits"

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INTRODUCTION

Magmatic Ni-Cu-PGE sulphide deposits are hosted towards the base of ultramafic and mafic igneous complexes and formed by efficient accumulation of immiscible sulphide liquids that scavenged chalcophile metals from the host silicate magma. Exploration work undertaken to identify Ni-Cu-PGE sulphide mineralization benefits from an understanding of whether the intrusions are anomalously depleted in highly chalcophile metals (PGE, Cu and Ni) as recorded by whole rock ratios or mineral phases, such as olivine. A measure of chalcophile depletion is given by comparison of whole rock Ni content with those expected for rocks of similar MgO content (Ni*) from S-undersaturated within plate basalts (Lightfoot et al., 2001). Another measure of chalcophile depletion is the comparison of whole rock Cu with Zr as both behave incompatibly in the absence of sulphide. Thus low Cu/Zr and Ni/Ni* whole rock ratios imply that sulphides segregated from the magma. Magmatic Fe-oxides (magnetite and/or ilmenite) commonly crystallize from mafic and intermediate magmas and contain several chalcophile elements in trace abundance. The purpose of this mineralogical study was to investigate whether the geochemistry of Fe-oxides (magnetite and ilmenite) in the intrusions that host Ni deposits record sulphide saturation and segregation and whether this could then be used to help vector towards a sulphide deposit at depth. Magnetite and ilmenite from fertile intrusions have significant Ni and Cu depletions compared to Fe-oxides from intrusions barren of Ni-deposits. Therefore the chemistry of Fe-oxide minerals has the potential to identify intrusions with buried Ni-sulphide mineralization. This study is part of the Targeted Geoscience Initiative 4 (TGI-4: 2011-2015)-Magmatic-Hydrothermal Nickel-Copper-Platinum Group Element-Chrome

Ore System Project (Ames and Houle, 2011; Ames et al., 2012). It builds on an earlier study by Beaudoin et al. (2012) using materials provided by Vale and the Geological Survey of Canada in support of the research. The aim of this Open File is to release the sample location, mineralogical and bulk rock geochemical databases produced for this study.

BACKGROUND AND OBJECTIVES

Magmatic Nickel-Copper-Platinum Group Element [Ni-Cu-PGE] sulphide deposits have accounted for most to the world's past and current production of nickel. Most Ni sulphide deposits consist of several closely adjacent but discrete orebodies having Ni grades typically between 0.7 and 3% and Cu grades between 0.2 and 2%. They share the following general characteristics:

- The host intrusions are either mafic or ultramafic in composition;
- Most deposits occur as concentrations of sulphides toward the base of their magmatic host bodies;
- Ni sulphide ores usually consist of a simple sulphide assemblage dominated by pyrrhotite-pentlandite-chalcopyrite found either as massive sulphides, sulphide matrix breccias, or disseminations of sulphides.

The role of magma dynamics in the concentration and enrichment of this important class of deposits has been much studied and the extraction of Ni from a magma to form a nickeliferous sulphide liquid plays a role in exploration strategy. For example, in ultramafic to mafic hosted deposits, Ni depletion in olivine can indicate sulphide segregation (e.g., Li et al., 2000, and references within). However, olivine is less common or absent in mafic to intermediate-hosted deposits. Instead, could chalcophile element depletion in Fe-oxides (i.e. magnetite and ilmenite) in this case be used to vector towards mineralization?

There is growing interest in using trace element chemistry of magnetite as an indicator mineral in the exploration for many types of ore deposits (e.g., Dupuis and Beaudoin, 2011; Nadoll et al., 2012; Rusk et al., 2010). Studies have shown that the trace element chemistry of magnetite, in particular Ni and Cr, from massive sulfide ore of magmatic Ni-Cu deposits can be used to discriminate these from deposits of hydrothermal origin, such as banded-iron formation, porphyry, volcanogenic massive sulphide and iron-oxide-copper-gold (Dupuis and Beaudoin, 2011; Dare et al. 2012). Furthermore, detailed studies on magnetite from massive sulphides of Sudbury and other Ni-Cu-PGE deposits, including Voisey's Bay, show that magnetite trace element chemistry is very sensitive to fractionation of the sulphide liquid and to changing sulphide mineralogy (Dalley et al., 2010; Dare et al., 2012; Boutroy et al., submitted). In both of these ore systems, the sulphide ores are hosted in igneous complexes that contain Fe-oxides, magnetite (Fe_2O_4) and ilmenite ($FeTiO_3$), throughout the overlying silicate sequence. The examination of these Fe-oxides in intrusions that host Ni-Cu-PGE deposits (i.e. fertile) could provide critical knowledge about the sulphide saturation and segregation history of the intrusion. A comparison of Fe-oxides from these fertile intrusions with those from intrusions that appear not to host Ni-Cu-PGE deposits (i.e., barren) could provide a novel geochemical approach in support of exploration targeting in mafic – intermediate intrusions worldwide.

The objectives of this study focused on:

- Investigating whether the trace element geochemistry of Fe-oxides (magnetite and ilmenite), found in intrusions hosting Ni-deposits, record sulphide saturation and segregation, which could then be used to vector towards a sulphide deposit at the base of or in the footwall of the intrusion.
- Gaining a better understanding of the evolution of Fe-oxide geochemistry during fractionation of the silicate liquid and the effect of sulphide saturation on the chemistry of the Fe-oxides.
- Comparing and contrasting the geochemical signature of Fe-oxides in both barren and mineralized/fertile intrusions of similar composition and genesis, in order to understand whether processes occurred that might generate mineralization. Barren site testing will be an effective method of validating the use of mineral-specific pathfinder elements both within a large intrusion that hosts many deposits and between deposit-hosting and barren intrusions.

STUDY AREAS

The study focused on two well known fertile igneous complexes that contain some of Canada's largest Ni-deposits: the 1.85 Ga Sudbury Igneous Complex, Ontario (Fig. 1), and the 1.34 Ga Voisey's Bay Intrusion within the Nain Plutonic Suite of Labrador (Fig. 2). The 1.33 Ga Newark Island layered intrusion, also within the Nain Plutonic Suite, Labrador (Fig. 2), was chosen to represent a mafic intrusion of similar age, composition and setting to Voisey's Bay but barren of any significant Ni-mineralization. Data were also collected from areas above the base of the Sudbury Igneous Complex that are devoid of known deposits and are thus termed “barren”. This Open File reports geochemical data (both mineral and whole rock) from these 3 igneous complexes: Sudbury, Voisey’s Bay and Newark Island.

This study compliments a series of studies carried out at UQAC on characterizing Fe-oxides from igneous complexes that host magmatic ore deposits (Fe-Ti-V-P and Ni-Cu-PGE-Cr). As such a background dataset of mineral chemistry and whole rock analyses) from massive Fe-oxide samples from igneous complexes that host Fe-Ti-V-P deposits, but are barren of Ni-deposits, is available from a series of UQAC theses and publications (Barnes et al., 2004; Dare et al., submitted; Fredette, 2006; Martin-Tanguay, 2012; Méric, 2011; Nabil, 2003; Néron, 2012; Sá et al., 2005; Tollari et al., 2008) for comparison with this study. The UQAC database, partially developed as part of the TGI4 project, comprises samples of massive Fe-oxides from layered mafic intrusions, such as the Bushveld Complex (South Africa), Sept Iles (Canada) and Rio Jacaré (Brazil), and from the anorthosite massif of Saguenay-Lac-St.-Jean (Quebec, Canada). Although these igneous complexes are barren of sulphide-rich Ni mineralization, nearly all have had some history of sulphide saturation: trace amounts of magmatic sulphides, some of which are enriched in PGE, formed either in the lower parts of their complex, such as the world class PGE-reef of the Bushveld Complex, or in the upper part with the massive oxide layers (e.g., Rio Jacaré: Sá et al., 2005).

GEOLOGICAL CONTEXT AND SAMPLING

1) Sudbury: The Sudbury Igneous Complex is host to one of the largest Ni-Cu-PGE mining districts in the world, containing over 90 deposits (Ames and Farrow, 2007). It is a differentiated impact melt sheet with a bulk composition of andesite (e.g., Ames et al., 2002; Gasparrini and Naldrett, 1972; Lightfoot et al., 2001; Lightfoot et al., 1997; Lightfoot and Zotov, 2005; Therriault et al., 2002): the Lower Unit comprises norite with intercumulus ilmenite ± Ti-rich magnetite; the Middle Unit is an oxide-rich gabbro (< 10% Fe-oxide and apatite) with cumulus ilmenite and Ti-rich magnetite; and the Upper Unit is a granophyre of granitic composition (Fig. 1). Sulphide-rich massive sulphide mineralization occurs towards the base of the igneous complex, in physical depressions called ‘embayments’, and in the footwall as veins and disseminations (see review in Farrow and Lightfoot, 2002).

The recent work of Darling et al. (2010) showed that, although sulphide saturation was widespread in the South Range of the Sudbury Igneous Complex, the largest depletion of chalcophile elements (monitored by whole rock Ni/Ni* and Cu/Zr ratios) was recorded in the Lower Unit norite (0.45 Ni/Ni*) that directly overlay mineralized embayments, i.e., in the Creighton and Gertrude area. Norite located a 4 - 6 kilometres away from mineralized embayments are less fertile (i.e. more “barren”) as they are less depleted in chalcophile elements (0.65 Ni/Ni*). Truly barren rocks are represented at Sudbury only by the marginal phase of the Offset dykes, which is a quenched quartz diorite (QD) that does not contain sulphides and represents the initial composition of the impact melt injected into radial fractures in the country rock before sulphide saturation (e.g., Grant and Bite, 1984; Lightfoot et al., 2001). Several phases of magma were later injected in the centre of these Offset dykes, termed inclusion-bearing quartz diorite (IQD), which contain inclusions of the marginal QD, footwall lithologies and blebby sulphides. The IQD dyke phase thus represents the Sudbury magma when it first achieved sulphide saturation (Lightfoot et al., 2001).

Previous work on the petrography and chemistry of Fe-oxides in the Sudbury Igneous Complex was carried out by Gasparrini and Naldrett (1972). On the North Range, both ilmenite and magnetite occur together throughout the 3 units of the differentiated melt sheet. However, on the South Range, ilmenite is the only intercumulus Fe-oxide phase in the Lower Unit and magnetite joins ilmenite as a cumulate phase in the oxide-rich Middle Unit. Magnetite is present only in a few cases in the South Range norite but probably exsolved from ilmenite rather than having crystallized from the magma (Gasparrini and Naldrett, 1972). No explanation was given for the different types of Fe-oxides between the North and South Range. Gasparrini and Naldrett (1972) showed that the composition of Cr and Ti in magnetite, analysed by electron microprobe, varied with stratigraphic height as a result of fractional crystallization of the melt sheet: the Cr content was highest in magnetite at the base of the Lower Unit norite (up to 13 wt.% Cr) and rapidly decreased up section to < 0.05 wt.% Cr in the Middle Unit. By contrast, the concentration of Ti in magnetite increased from 1-2 wt.% at the base to 23 wt.% in the Middle Unit.

Disseminated magmatic sulfides (< 10% of pyrrhotite, pentlandite and some chalcopyrite) are common throughout the Lower Unit on the North Range above a mineralized embayment: from the felsic norite to disseminated ore at the base. By contrast, disseminated magmatic sulfides only occur in the Sublayer at the base of embayment in the South Range and form disseminated ore (Lightfoot and Zotov, 2005). The formation of Fe-oxides on the margin of sulfide droplets is a common phenomenon at Sudbury. Previous studies (Naldrett, 1969; Naldrett et al., 2000) has attributed this to the diffusion of oxygen out of small droplets of sulfide liquid and its combination with Ti and Fe from the silicate melt to form ilmenite and/or titanomagnetite at the sulfide/silicate margin. However, the chemistry of these Fe-oxides associated with disseminated sulfides has not previously been documented. In much larger accumulations of sulfide liquid, such as in contact-style mineralization, the oxygen cannot diffuse out to the silicate liquid and thus the oxygen content increases upon crystallization of MSS until magnetite also crystallizes directly from the sulfide liquid. The trace elements of magnetite in massive sulfides from both South Range (Creighton mine) and North Range settings (McCreedy East deposits) have recently been determined by electron microprobe and laser ablation ICP-MS by Dare et al. (2012). The composition of magnetite is controlled by crystal fractionation of the sulfide melt: all lithophile elements (including Ti and Cr) systematically decrease whereas some of the chalcophile elements (such as Sn and Ni) increase.

A total of 69 samples (chosen for mineral chemistry from ~ 150 thin sections) were selected from stratigraphic traverses (both surface exposures or drill core; Ames et al. 2001, 2002; Vale Ltd.), from the base of the Lower Unit to the top of the Middle Unit where possible, both directly above (fertile) and away from ("barren") mineralized embayments in the South Range (in the vicinity of Creighton embayment) and North Range (in the vicinity of Levack embayment: Fig. 1). A few of these samples were also chosen from the truly barren QD phase and the mineralized IQD phase of the Worthington Offset dyke on the South Range (Fig. 1). The base of the Middle Unit (TZG) was taken as a paleo-horizontal marker in order to calculate true depth (in metres) above (+ve values) and below (-ve values). A total of 349 samples analysed for whole rock geochemistry from these 3 study areas are compiled in Appendix 4.

2) Voisey's Bay intrusion: The Voisey's Bay intrusion (1333 Ma) is the oldest and least contaminated mafic intrusion of the Nain Plutonic Suite (Amelin et al., 2000), Labrador. Upon its discovery, it defined a new tectonic setting for world class Ni-deposits (mafic rocks in anorthosite complexes in anorogenic settings). Numerous studies have described the Voisey's Bay intrusion and its Ni-Cu-Co deposits, e.g., Ryan et al. (1995), Naldrett et al. (1996), Li and Naldrett (1999), Naldrett et al. (2000), Li et al. (2000), Lightfoot and Naldrett (1999) and Lightfoot et al. (2012). However we are the first to characterize the geochemistry of the Fe-oxides in the host intrusion.

The intrusion contains troctolite, olivine gabbro, olivine norite, olivine ferrogabbro and ferrogabbro. Sulphide mineralization is associated with the more primitive rocks (troctolite/olivine gabbro; Fig. 3) in the conduit dykes (e.g., Ovoid Deposit) and at the opening of these dykes into the upper chamber (Eastern Deeps). The Eastern Deeps chamber contains varied-textured troctolite (VTT) in the lower part, which is weakly mineralized (up to 25% sulphides), overlain by normal troctolite (NTT) that grades into olivine gabbro, both of which are sulphide-poor (Fig. 3b). Massive sulphides occur at the opening of the feeder dyke into the Eastern Deeps chamber. The upper unit (NTT) is sulphide-poor and is not depleted in Ni (Lightfoot et al., 2012). Li et al. (2000) proposed that the troctolite (NTT and VTT) in the Eastern Deeps was a fresh surge of primitive magma (undersaturated in S) that picked up sulphides that formed in the lower chamber (Reid Brook Zone) and deposited them in the upper chamber. However, they suggest that this magma may have interacted with the pre-existing sulphides enriching them in Ni, as the disseminated sulphides in Eastern Deeps have higher Ni tenors than the massive ore of Easter Deeps and the Ovoid. Ilmenite is the dominant oxide, whereas magnetite is rare, with a few layers of massive ilmenite (cumulus) present in the upper part of normal troctolite in Eastern Deeps (Li and Naldrett, 1999).

A total of 22 samples (Fig. 3c) of variable-textured troctolite, normal troctolite, olivine gabbro and 1 cross-cutting syenite sill of the Eastern Deeps chamber were selected to make thin sections from 2 drill cores (VB266 and VB254), which are described in detail by Lightfoot et al. (2012). Lithologies analyzed for mineral chemistry comprise 14 troctolite, 4 olivine gabbro and 1 syenite. Five troctolites (VTT) are S-rich (> 5% sulphides, 0.65 to 7 wt.% S) and the remaining samples are S-poor (0.01 to 0.4 wt. % S). One sample of mineralized 'leopard troctolite' from the Ovoid (provided by S.-J. Barnes) was also analyzed for comparison. A total of 117 samples analysed for whole rock geochemistry from these 2 drill cores are compiled in Appendix 4.

3) *Newark Island Layered Intrusion*: This intrusion, situated ~ 50 km northeast of Voisey's Bay, is also part of the Nain Plutonic Suite (Fig. 2). The geology, petrography and mineral chemistry by electron microprobe only of the Newark Island layered intrusion was described by Wiebe (1987, 1988) and Wiebe and Snyder (1993) from which the following is summarized. The intrusion is divided into a lower Layered Series (subdivided further into Lower Zone and Upper Zone) and an upper Hybrid Series. Large transgressive trough structures appear to cut through the stratigraphy. Our 96 samples (analysed for whole rock geochemistry, compiled in Appendix 4) are from all 3 Units of the layered intrusion (Fig. 4). The Lower Zone comprises mainly troctolite and olivine gabbro which contains trace amounts (< 1 modal %) of intercumulus Fe-oxides (mainly ilmenite). The Upper Zone comprises mainly olivine gabbro and gabbro, with clinopyroxene as a cumulate phase, together with a moderate amount (10-40%) of cumulus Fe-oxides. The contact between the Lower and Upper Zones is marked by the presence of cumulate ilmenite, which is the dominant Fe-oxide phase, followed shortly by Ti-rich magnetite and then pyrrhotite. Apatite (< 10%) only appears as a cumulus phase at the very top of the Upper Zone and is not present in any of our samples. The Hybrid Series contains repetitive layers of mafic and silicic cumulates (diorite, monzonite and granite) cross cut by trough structures interpreted as feeder dykes of granitic magma into the magma chamber. Mafic rocks from the lower Layered Series were preferentially selected in order to compare Newark Island Layered intrusion (example of a barren intrusion without significant Ni mineralisation) with the mafic rocks of Voisey's Bay (example of a fertile intrusion).

The locations of all the Newark samples analysed for mineral chemistry (a total of 18 selected from 20 thin sections) are plotted in Figure 4. The samples analysed represent all of the lithological units: Lower Layered Series (n=9), Upper Hybrid Series (n = 3) and the cross-cutting

Troughs that fed the Upper Series (n = 6). Lithologies vary from olivine gabbro (n = 7) to gabbro (n = 9) and oxide-rich gabbro (n = 2). Magmatic sulphides are present in trace amount (< 2 modal %) in some samples and comprise pyrrhotite and chalcopyrite; pentlandite is rare. The extreme low abundance of S in the whole rock (< 0.1 wt.%) of samples from the Hybrid Series indicates that these sulphides are probably intercumulus and that the magma was not saturated in S. However, the Layered Series rocks contain 0.12 – 0.62 wt.% S which indicates that these sulphides are cumulus after sulphide saturation. However, there is no significant Ni mineralization present in the Layered Series rocks.

ANALYTICAL TECHNIQUES

A) BULK ROCK GEOCHEMISTRY

The bulk rock geochemistry for rock samples from Sudbury were analyzed by 4 different laboratories (Geological Survey of Canada, ACME, Activation and SGS geochemical laboratories) by standard methods as noted in the database (Appendix 4). 180 samples from the fertile Creighton area (Figs. 1D, A1), 19 samples from the fertile Levack area (Figs. 1B, A4) and 7 samples from the Worthington offset area (Figs. 1E, A3) were analyzed (pre-2004) by the Geological Survey of Canada laboratories in Ottawa (Table A4.1). After 2004, standard geochemical work for this study was undertaken by Activation Laboratories. Barren samples (n = 100) from the west of Creighton embayment on the South Range (Fig. A2, Table A4.2) were analysed by Vale Ltd. at SGS geochemical laboratory: ICP-MS analysis was carried out after 4 acid digestion of hydrous powders, XRF for selected traces only (Cr, Ba, Nb, Rb, Y and Zr) and S by combustion and infrared analysis using Leco. The remaining North Range samples (9 from the fertile Levack area and 34 from the barren area southwest of Levack: Figs. 1B, A4) were analysed by Vale Ltd. at ACME laboratories using ICP-MS analysis after 4 acid digestion of hydrous powders (Table A4.3).

Whole rock major and trace element geochemistry of 117 samples from the Voisey's Bay intrusion (Table A4.4) and 96 samples from the Newark Island layered intrusion (Table A4.5; Fig. A4.5) were analysed by Vale Ltd. at SGS geochemical laboratories (for XRF on majors and selected traces, S by combustion and infrared analysis using Leco and LOI by gravimetry) and the

Geological Survey of Canada (for ICP-MS analysis after 4 acid digestion). Some of these data (MgO, Ni, Cu and S) were published together with PGE and Au data in Lightfoot et al. (2012) and are available from the Mineralium Deposita repository of unpublished data and the GAC-MAC field guide on Voisey's Bay (Lesher et al. 2008).

B) MINERAL CHEMISTRY

Over 170 polished thin sections were examined from the 3 study areas in order to chose samples (107 in total), covering the full stratigraphy where possible, that contained Fe-oxide grains suitable for analysis (i.e., least altered, larger than 80 µm). Brief descriptions and sample locations of the thin sections, and their link to whole rock analyses, are given in Appendix 1.

In-situ determination of trace elements in the Fe-oxides and olivine were carried out on polished thin sections using: 1) electron microprobe (EMP) at Université Laval, Quebec City, following normal protocol described in Dare et al. (2012); and 2) laser ablation-ICP-MS (LA-ICP-MS) at LabMaTer, Université du Québec à Chicoutimi (UQAC) for ^{24}Mg, ^{25}Mg, ^{27}Al, ^{29}Si, ^{31}P, ^{44}Ca, ^{34}S, ^{45}Sc, ^{47}Ti, ^{49}Ti, ^{51}V, ^{52}Cr, ^{53}Cr, ^{55}Mn, ^{57}Fe, ^{59}Co, ^{60}Ni, ^{63}Cu, ^{65}Cu, ^{66}Zn, ^{69}Ga, ^{71}Ga, ^{74}Ge, ^{89}Y, ^{90}Zr, ^{92}Zr, ^{93}Nb, ^{95}Mo, ^{101}Ru, ^{105}Pd, ^{118}Sn, ^{139}La, ^{147}Sm, ^{172}Yb, ^{178}Hf, ^{181}Ta, ^{182}W, ^{187}Re, ^{193}Ir, ^{195}Pt, ^{197}Au, ^{208}Pb and ^{209}Bi. Details of the analytical procedure and detection limits are given in Table 1. The analysis of certified reference materials (GSD and GOR-128g) presented in Table 2 shows that the accuracy and precision are generally good (most < 10% and only < 15%). For natural magnetite (in-house monitor BC28) the accuracy and precision are generally < 15% for most elements, except Cu which is heterogeneously distributed (Table 2). Details of possible isotopic interferences are discussed in Dare et al. (submitted) and summarized here. For Mg, Ti, Cu and Ga, multiple isotopes were monitored and produce the same results (e.g., Tables A4 in Appendix 4). Although there is a possible $^{47,49}Ti$ plus ^{16}O interference on both isotopes of Cu ($^{63,65}Cu$), it appears to be negligible as the LA-ICP-MS results for Cu in Ti-rich magnetite (in house monitor BC28) agree with the working values (by INAA). However, at low levels of Cu (< 10 ppm) the ^{65}Cu isotope is commonly double that of ^{63}Cu and thus the latter is the preferred isotope. The contribution of ^{25}Mg plus ^{40}Ar to ^{65}Cu is also considered negligible: olivine contains no Cu, as shown by ^{63}Cu, and thus can be used to estimate that 1 wt.% Mg gives an interference of 0.12 ppm on the ^{65}Cu isotope. Even for Mg-bearing ilmenite this is less than 10% of the measured value of Cu (> 1 ppm). However, there could be important interferences on $^{90,92}Zr$ and ^{93}Nb. Dare et al. (2013) showed that the ^{50}Ti plus ^{40}Ar interference on ^{90}Zr can be significant at > 5 wt.% Ti in magnetite and important for ilmenite (^{90}Zr is double the value of ^{92}Zr: Table A4.1). However, there is negligible interference from $^{50,52,53}Cr$ plus ^{40}argide on $^{90,92}Zr$ and ^{93}Nb as magnetite contains < 1 wt.% Cr. Thus ^{92}Zr is the preferred isotope.

It is important to note that the two in-situ analytical methods give results of different processes at different scales: The small beam size of the electron microprobe (5µm) allowed us to identify exsolution lamellae (ilmenite, spinel) and to analyze the composition of the Fe-oxide host after subsolidus exsolution. By contrast, the larger beam size of the LA-ICP-MS (33-75 µm) ablated both the Fe-oxide and exsolution products and thus represents the original high temperature Fe-oxide that crystallized from the liquid, before subsolidus exsolution processes took place at lower temperatures (e.g., Dare et al., 2012). Thus the average of the ablation line gives a better representation of the composition of the high temperature magnetite than the electron microprobe. In order to compare LA-ICP-MS results with the electron microprobe results, the latter data were recalculated to include the proportion of exsolution lamellae present in the grain (estimated visually). In general, the results obtained by LA-ICP-MS for Fe-oxides and olivine are in good agreement with those obtained by electron microprobe (Figs. 5 and 6), for concentrations of elements above the detection limit of the electron microprobe.

In order to compare the fertile (Voisey's Bay) and barren (Newark Island) intrusions of the Nain Plutonic Suite, additional silicate (e.g., plagioclase, pyroxene, biotite, apatite) and sulphide minerals were analysed by electron microprobe at Université Laval, Quebec City, using normal conditions of 15kV, 20 nA, a beam diameter of 3µm and counting times of 20s.

RESULTS

The minerals and total number of Fe-oxides, silicate and sulphide minerals analyzed in this study and presented in this Open File is summarized in Table 3. The mineral databases of laser-ablation ICP-MS results of ilmenite, magnetite and olivine are presented in full in Appendix 2 (Tables A2.1-2.3). The results averaged per thin section are given below in Tables 4 – 8 and also as Excel spreadsheets in Tables A2.4-2.6 of Appendix 2. All values below the detection limit have been replaced by the corresponding value of the detection limit. The entire electron microprobe (EMP) results for the Fe-oxides, silicates and sulphides are given in full and as averages per thin section in electronic format in Appendix 3. The compiled whole rock databases (562 analyses) that compliment this study, and are used to calculate chalcophile depletion ratios (such as Ni/Ni* and Cu/Zr), are given also in Appendix 4 together with information on analytical techniques used and their locations (Fig. A4 in Appendix 4).

This *Sudbury mineral database* comprises Fe-oxides analyses from a total of 69 samples of the Sudbury Igneous Complex. Ilmenite (Table 4) was analyzed in all of the samples (total of 290 grains) whereas magnetite (Table 6) suitable for analysis was present in 32 samples (125 grains) by LA-ICP-MS and in 34 samples (124 grains) by EMP. The silicate minerals plagioclase, pyroxene, biotite and apatite were analyzed by EMP only (Appendix 3).

The Nain Plutonic Suite mineral database comprises Fe-oxide analyses from a total of 38 samples (19 from Voisey's Bay and 19 from Newark Island). Ilmenite (Table 5) was analyzed in all of the samples (total of 168 grains) whereas magnetite (Table 7) was less common and present only in 6 samples (24 grains) from Voisey's Bay and 15 samples (76 grains) from Newark Island. In addition, 2 small grains of chromite present in the more mafic samples from Voisey's Bay were analyzed by EMP only. Olivine (Table 8) was also analyzed in 15 samples (79 grains) from Voisey's Bay and in 10 samples from Newark Island (46 grains). Silicates other than olivine (plagioclase, pyroxene, biotite and apatite) and sulphides were analyzed by EMP only and the results are given in Appendix 3.

SUMMARY

The TGI4 databases of geochemistry, electron microprobe and laser ablation ICP-MS results generated in this study presented here will be used in a forthcoming journal publication. The following summary of our interpretation of these results was modified from the GAC-MAC abstract presented in May 2013 in Winnipeg, Manitoba in the Special Session on "Magmatic Ni-

Cu-PGE-Cr Deposits: Ore-Forming Processes with Implications for Exploration" (Dare et al. 2013 GAC-MAC abstract).

The purpose of this mineralogical study was to investigate whether the geochemistry of Fe-oxides (magnetite and ilmenite) in the intrusions that host Ni deposits record sulphide saturation and segregation and whether this could then be used as an exploration tool to vector towards a sulphide deposit at depth. A suite of 25 trace elements were determined in magnetite and ilmenite, by laser ablation ICP-MS at LabMaTer (UQAC), from a variety of barren and fertile igneous complexes, including two of Canada's largest Ni-deposits: the 1.85 Ga Sudbury Igneous Complex (Ontario) and 1.34 Ga Voisey's Bay (Newfoundland). Other barren igneous complexes investigated (Dare et al., submitted) and that complement this study comprise layered mafic intrusions (Bushveld, South Africa and Sept Iles, Quebec) and anorthosite suites (Saguenay-Lac-St.-Jean, Quebec) that host Fe-Ti-V-P deposits, some of which contain trace amounts of magmatic sulphides but no Ni-Cu-PGE deposits. Mafic rocks of the 1.33 Ga Newark Island layered intrusion (Newfoundland) were also studied as they are similar in composition and setting to Voisey's Bay but barren of Ni Cu-PGE deposits.

In sulphide-undersaturated magmas, Cu, Sn, Mo and Zn are incompatible during fractionation and thus increase in concentration in both magnetite and ilmenite. Upon sulphide saturation and the formation of a trace amount of sulphide, only Cu is depleted in the silicate magma relative to the other incompatible elements. Cu depletion as recorded by Fe-oxides is a sensitive indicator of sulphide saturation and can be diagnostic of whether a Ni-bearing sulphide deposit formed if the Cu depletion occurred early. By contrast, Ni and Co are compatible during fractionation, partitioning into olivine, orthopyroxene and, where present, sulphide, and their concentration steadily decreases in the Fe-oxides together with Cr. Fe-oxides from barren complexes plot on a single Ni-Cr trend but Fe-oxides from fertile complexes, hosting Ni-Cu-PGE deposits, plot on a parallel Ni-Cr trend displaced to lower Ni concentration. Ni depletion is therefore recorded in Fe-oxides and has the potential to identify intrusions with buried Ni-sulphide mineralization. The advantages of using Fe-oxides as an exploration tool include their resistance to post-magmatic processes such as alteration and their preservation and easy recovery in glacial till.

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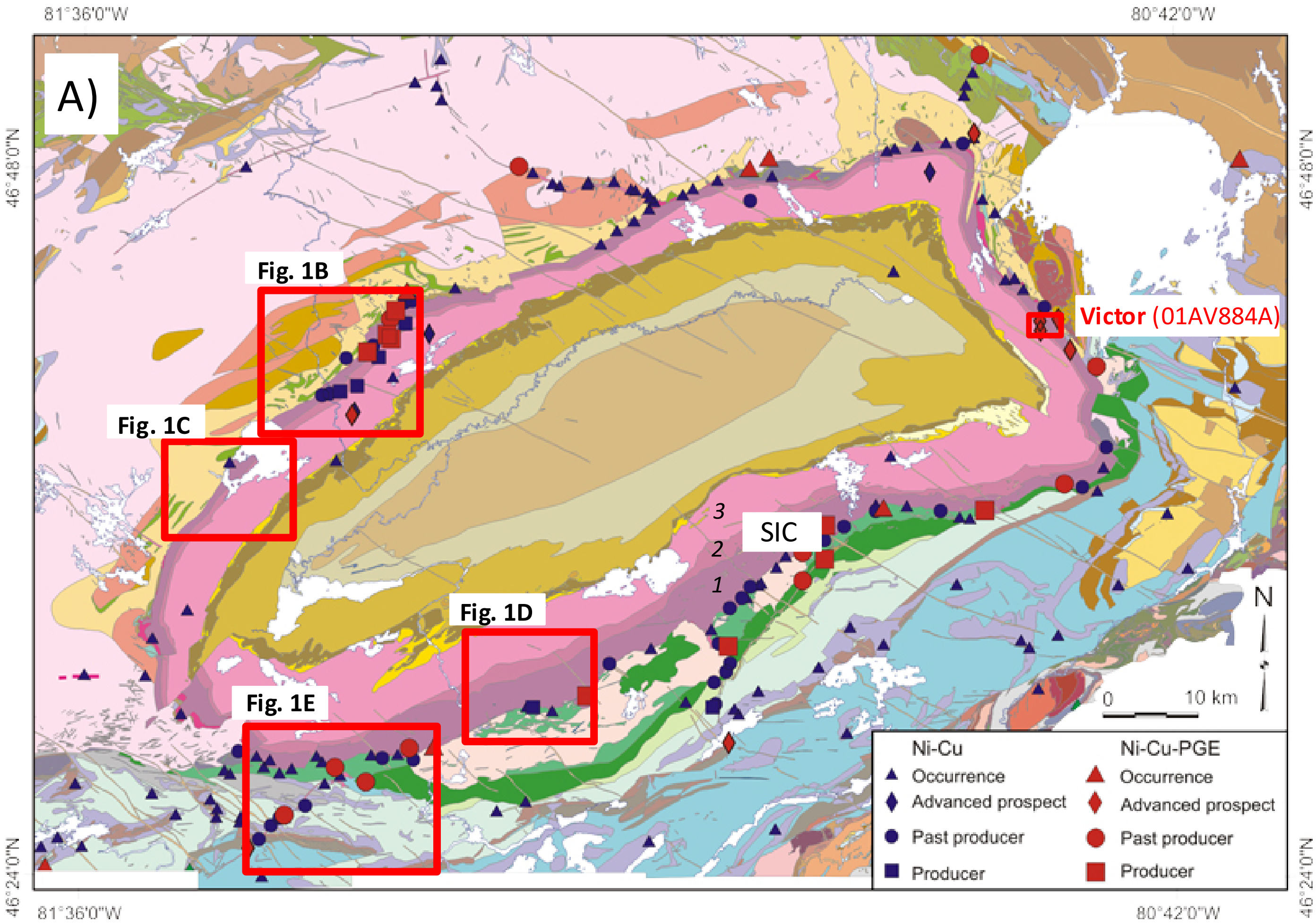

Figure 1. A) Geological map (Ames et al. 2005) of the Sudbury Igneous Complex (SIC) showing Ni-Cu-PGE mineralization near the base of the differentiated impact melt sheet: 1 – Lower Unit norite, 2 – Middle Unit oxide-rich gabbro (also termed transition zone gabbro-TZG), 3 – Upper Unit granophyre.

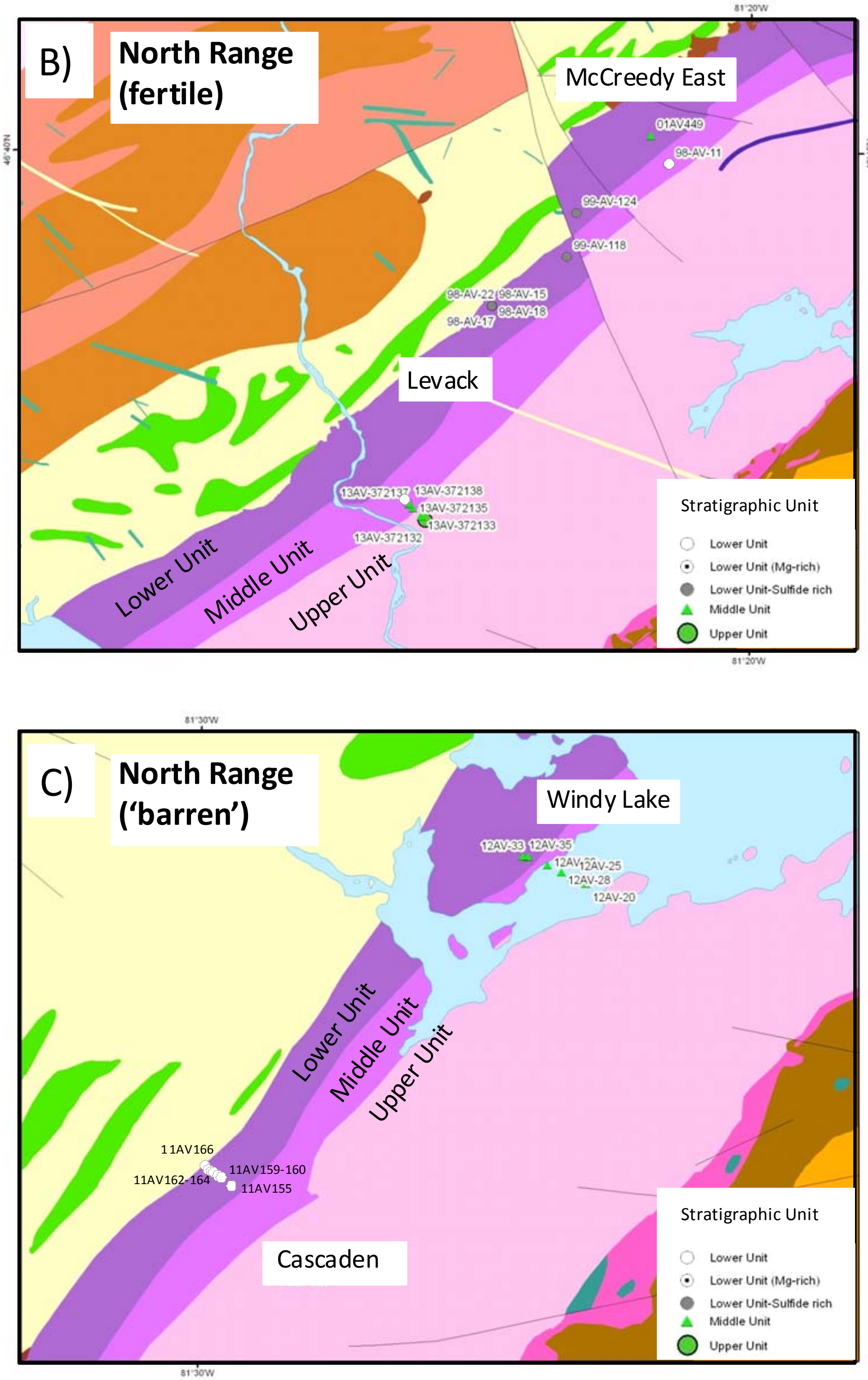

Figure 1 cont. North Range samples used in the mineral chemistry study (taken from mainly from drill core or underground and projected to surface). B) Fertile samples are from the Levack embayment (near Levack and McCreedy East mines). C) 'Barren' samples are from Cascaden township and Windy Lake.

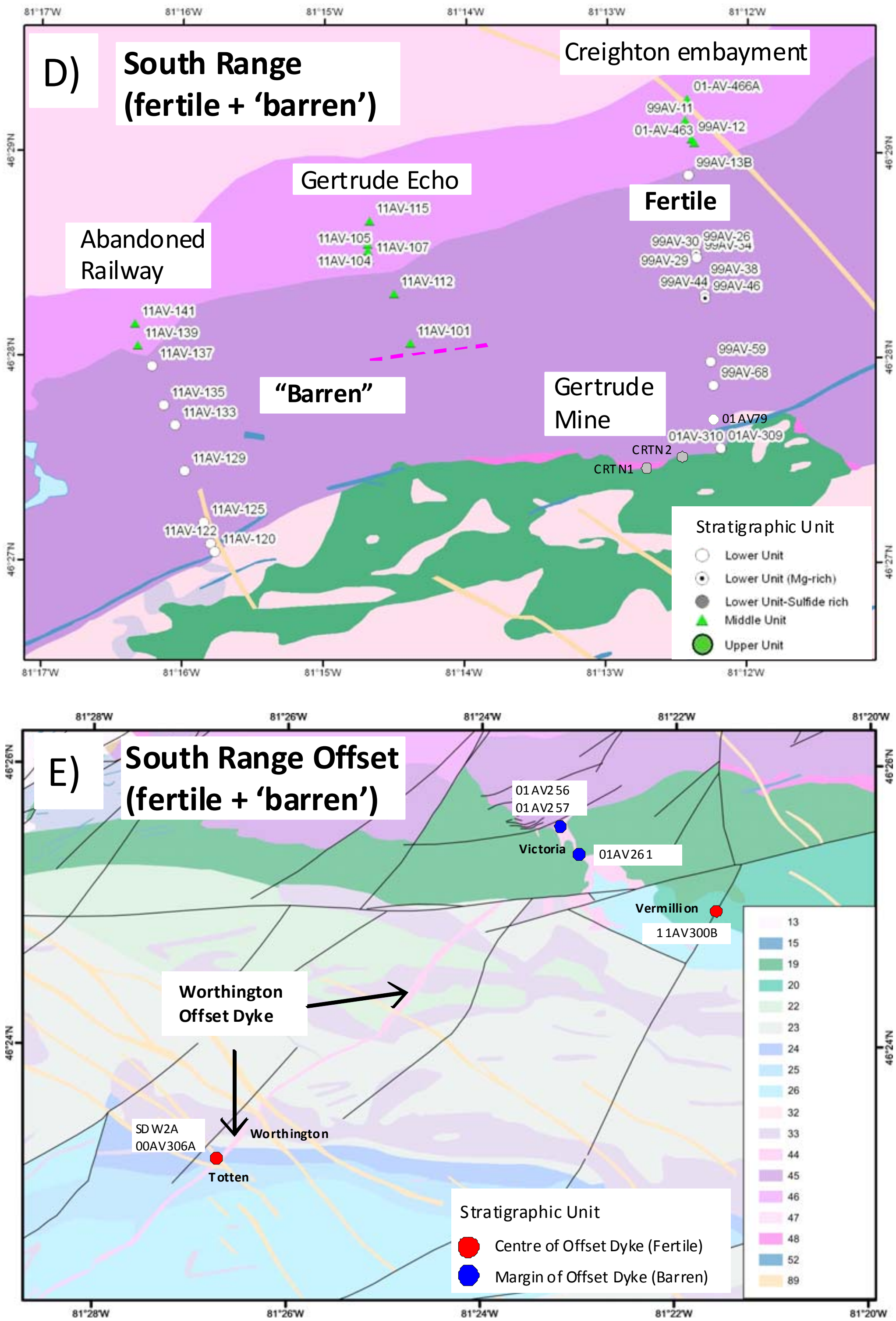

Figure 1 cont. South Range samples used in the mineral chemistry study (mainly from surface exposure). D) Fertile samples are from Highway 144 traverse of the Creighton embayment. More ‘barren’ samples are from the abandoned railway/Gertrude areas published in Darling et al. (2010). Pink dashed line - Modification to lower boundary of Middle Unit based on sampling. E) Fertile and more ‘barren’ samples of inclusion-bearing quartz diorite (IQD) and marginal quartz diorite (QD), respectively, from the Worthington offset dyke on the South Range. Sample from Vermillion (11AV300B) is from a small offset dyke pod not visible on the map.

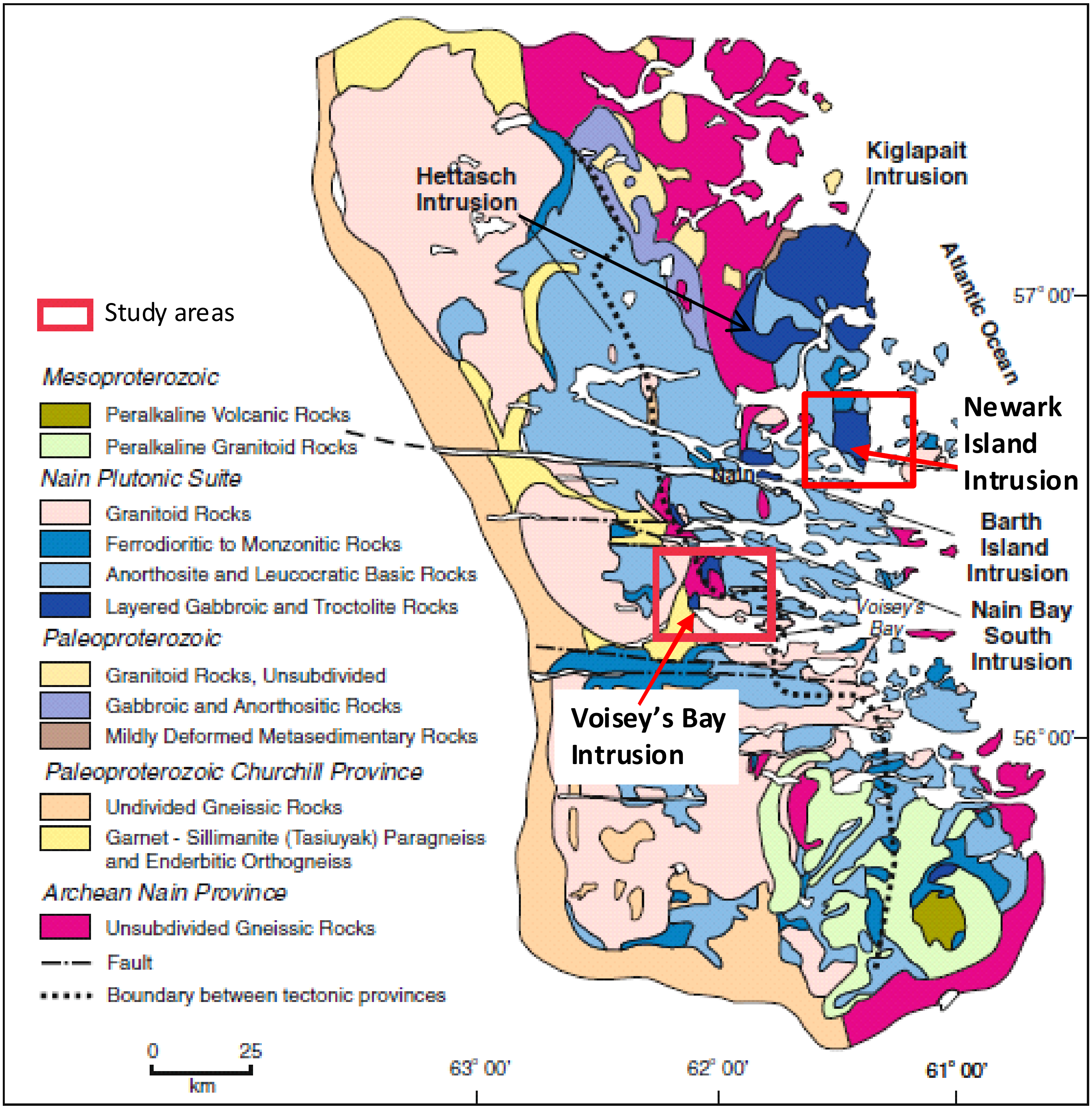

Figure 2. Geological map of the Nain Plutonic Suite, Labrador, showing the location of Voisey's Bay Intrusion and Newark Island Layered Intrusion investigated in this study. Taken from Lightfoot et al. (2012), modified from Ryan (2000).

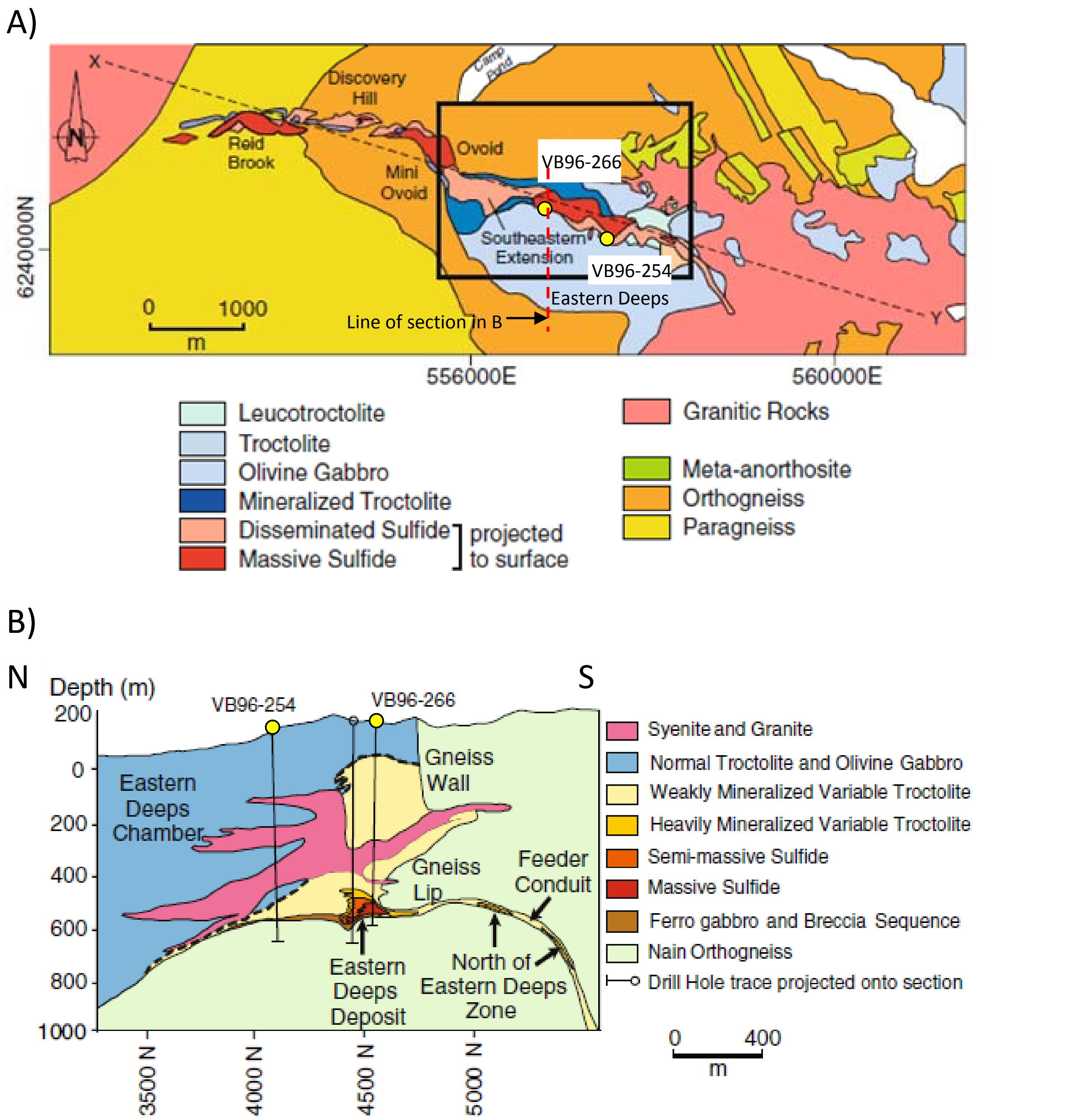

Figure 3. A) Geological map showing the projections to surface of the massive and disseminated sulphide mineralization within Voisey's Bay intrusion in Nain province, Labrador. The location of the drill core (VB96-266 and VB96-254) used in this study is shown as yellow circles. B) West-facing section showing the geology of the Eastern Deeps Intrusion and location of the deposit at the entry point of the dyke at the base of the north wall. Location of drill holes are projected onto the section. Maps modified from Lightfoot et al. (2012).

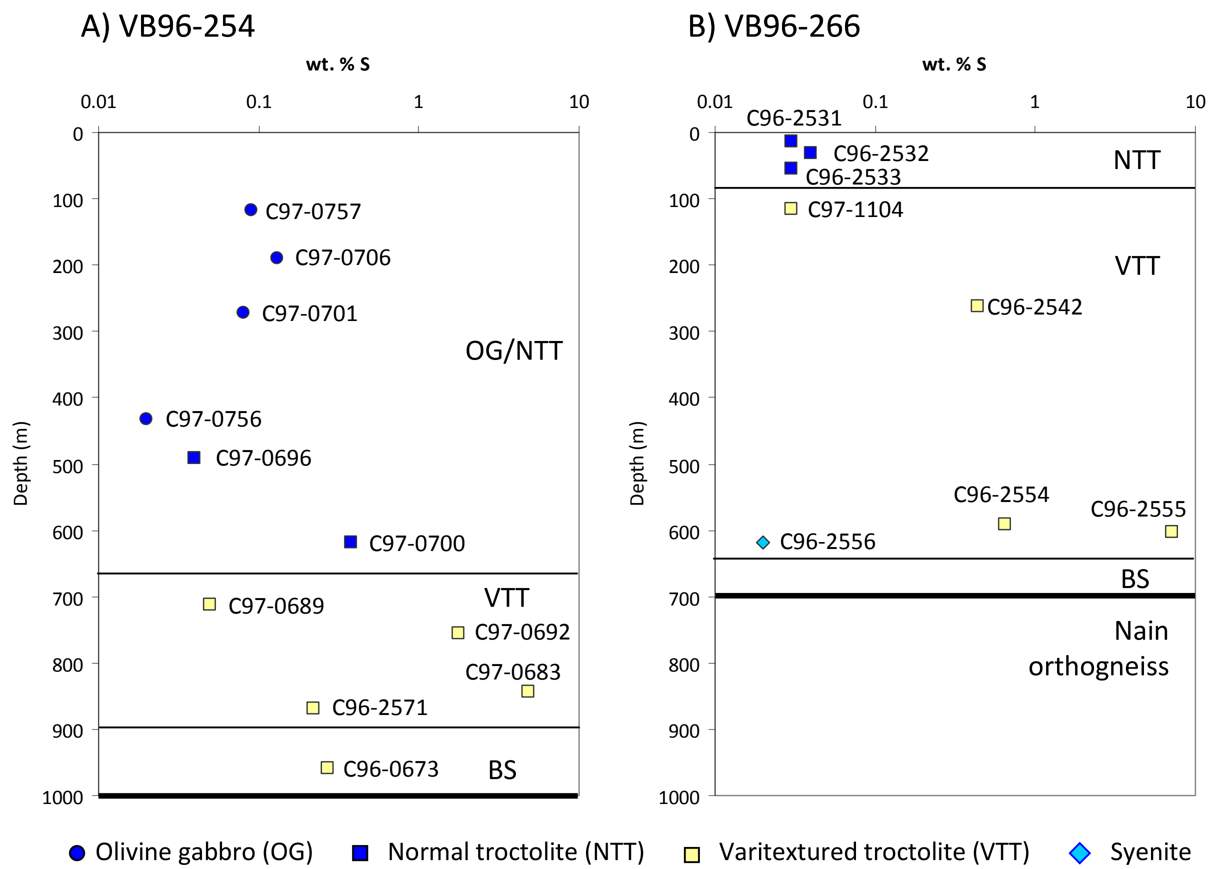

Figure 3 cont. C) Variation in sulfur (S wt.%) content of samples with stratigraphic depth in drill core A) VB96-254 and B) VB96-266 from Eastern Deeps Intrusion of Voisey's Bay deposit. *BS* - breccia sequence.

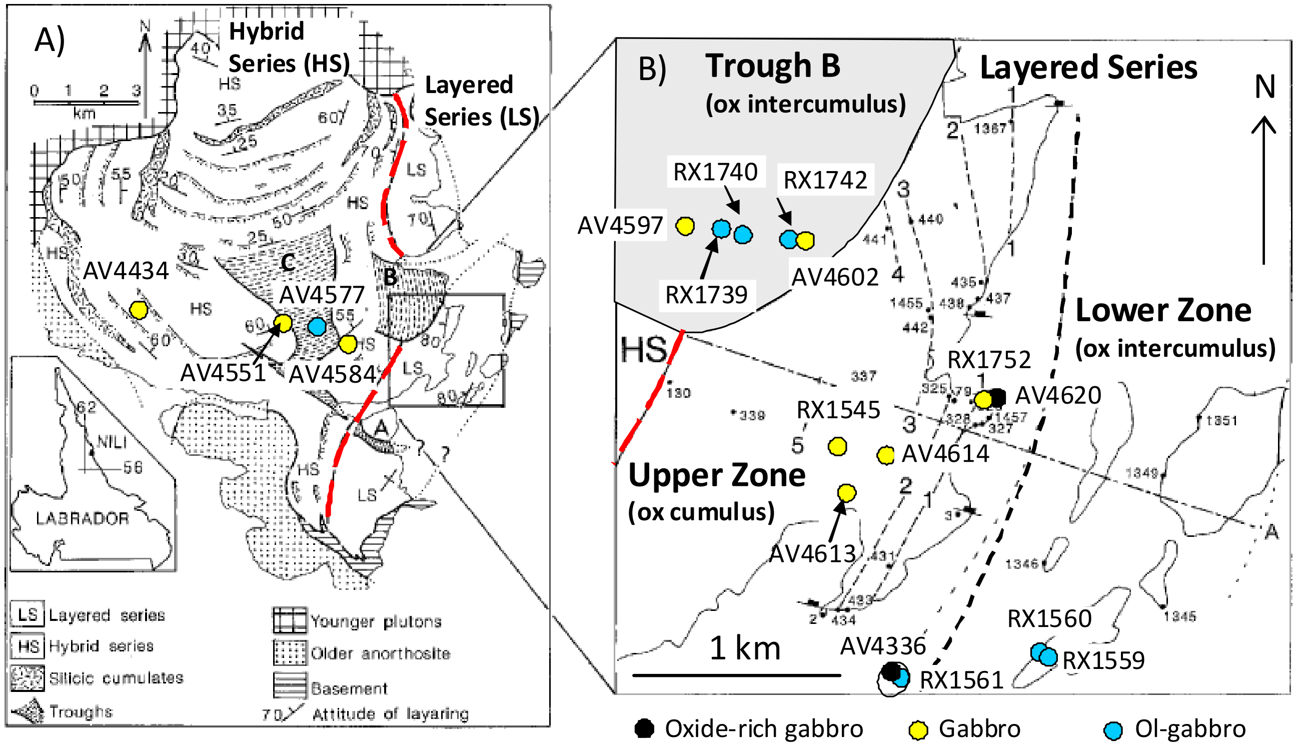

Figure 4. A) Geological map of the Newark Island layered intrusion in Nain province, Labrador. Red dashed line marks the division between the lower Layered Series (LS) to the east and upper Hybrid Series (HS) to the west. Cross-cutting Troughs are labelled A-C after Wiebe and Snyder (1993). B) Detailed map of Layered Series, which is divided into Lower Zone and Upper Zone, and Trough B. Coloured circles represent sample locations according to rock type. Maps taken from Wiebe and Snyder (1993).

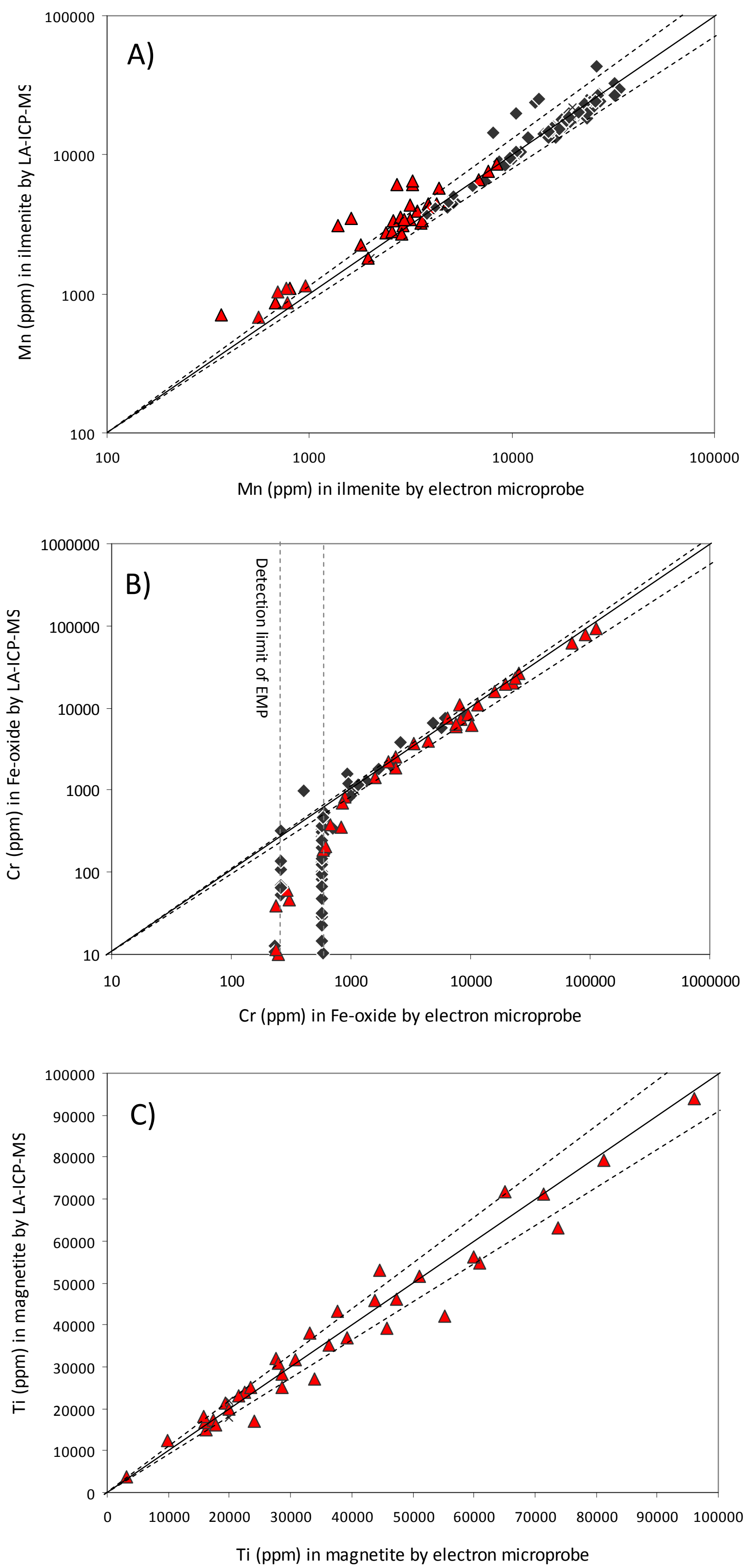

Figure 5. Comparison of results by electron microprobe and laser ablation ICP-MS for determining Mn (A,) Cr (B) and Ti (C) in ilmenite (black diamonds) and magnetite (red triangles). Dashed lines represent 10% relative difference from the 1: 1 line. In B) the detection limit for Cr changed from 600 to 250 ppm for the last set of analyses.

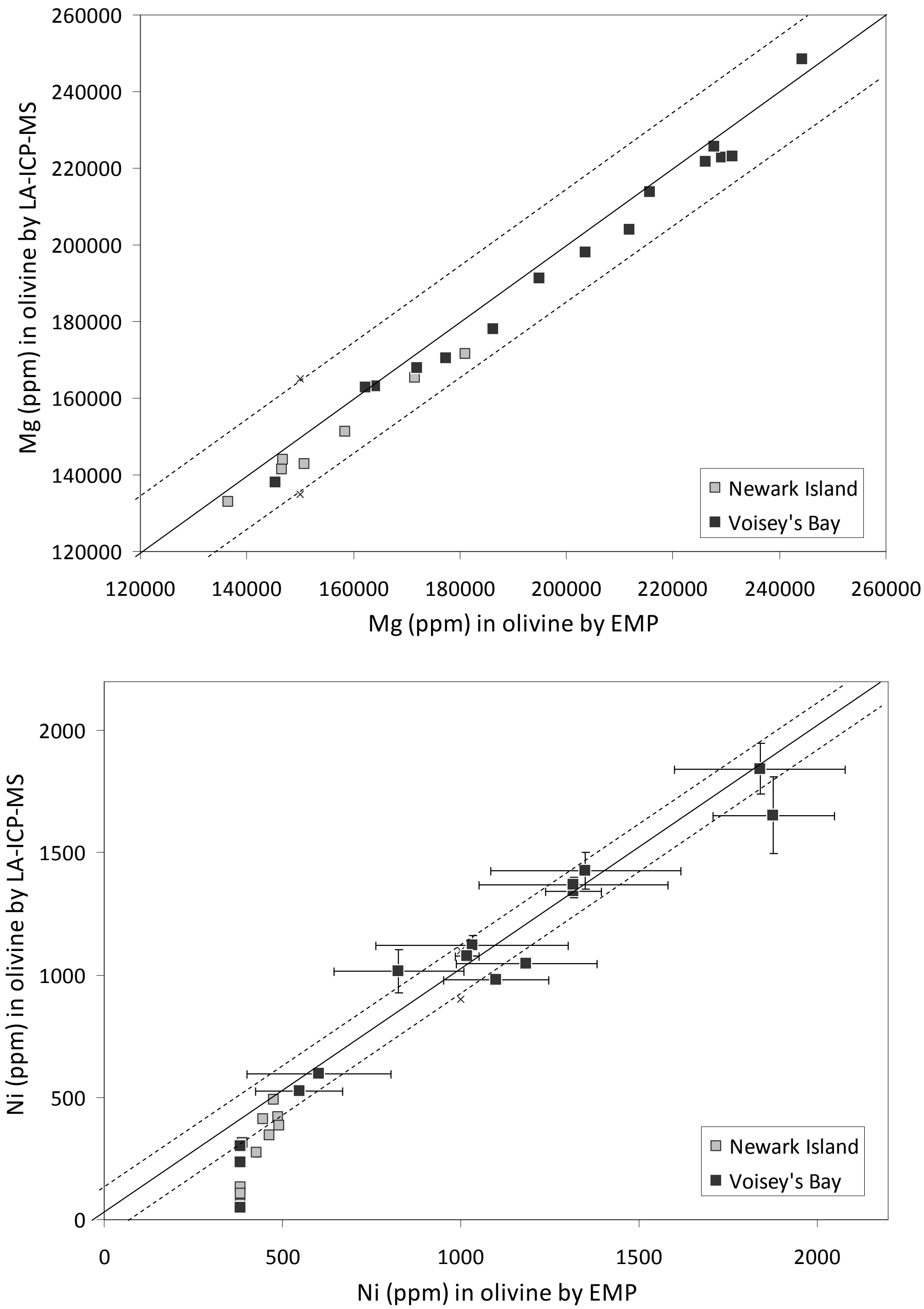

Figure 6. Comparison of results by electron microprobe (EMP) and laser ablation ICP-MS for determining Mg (A) and Ni (B) in olivine from Nain Plutonic Suite. Dashed lines represent 10% relative difference from the 1: 1 solid line. In B) the error bars represent the natural variation with olivine measured by EMP from core and rim.

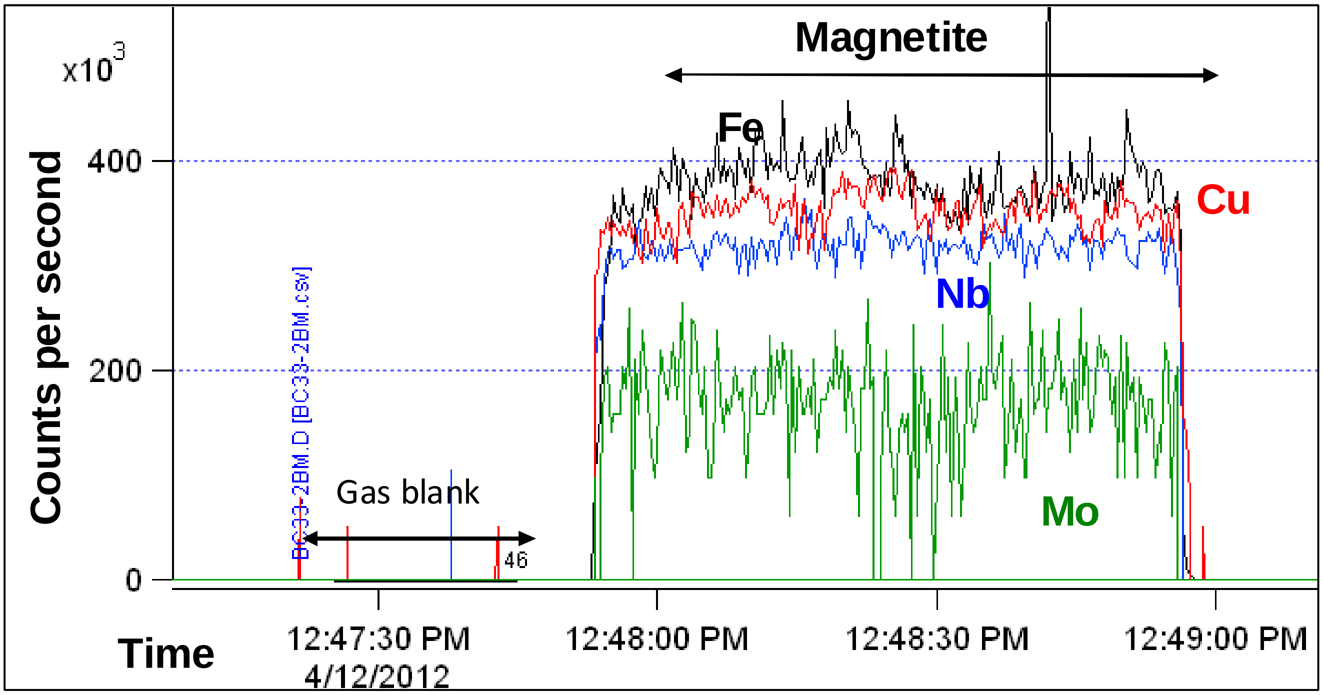

Figure 7. Time resolved spectra (LA-ICP-MS) for magnetite from S-poor layer of the Bushveld Complex containing Cu (10 ppm), Mo (0.9 ppm) and Nb (2 ppm) in solid solution.

Table 1: Analytical details for the Laser Ablation-ICP-MS analysis of Fe-oxides and olivine at UQAC

Laser ablation system	Resonetics Resolution M-50 Excimer 193 nm
ICP-MS	Agilent 7700x
Laser frequency	10Hz
Pulse Energy	5 mJ/pulse
Stage Speed	3 - 10 µm/s
Beam size	33 - 75 µm
Analysis	Line raster (~ 300 um long)
	30 s gas blank 60 s of signal
Gas flow	Helium (650 ml/min) Nitrogen (1 ml/min)
	Argon (0.7 - 0.9 ml/min)
Internal standard	Fe for Fe-oxides; Si for olivine (data from EMP)
Calibration Reference Material	GSE-1g (USGS-synthetic glass) for all elements except GSD-1g (USGS-synthetic glass) for P
Monitor Reference Material	GSD-1g and GOR-128g (natural glass, komatiite composition)
In-house monitor	Magnetite from Bushveld (BC28: published in Dare et al. 2012)
Monitor signal for inclusions	S, Si, P and Ca
Data reduction	Iolite software (Paton et al. 2011)

Isotope	Detection limit (75 µm beam) (ppm)	Isotope	Detection limit (75 µm beam) (ppm)
24Mg	0.011	89Y	0.001
25Mg	0.105	90Zr	0.002
27Al	0.073	92Zr	0.004
29Si	500	93Nb	0.001
31P	5	95Mo	0.005
44Ca	15	101Ru*	0.006
45Sc	0.014	105Pd*	0.004
47Ti	0.046	118Sn	0.030
49Ti	0.161	139La	0.010
51V	0.010	147Sm	0.030
52Cr	0.189	172Yb	0.020
53Cr	0.260	178Hf	0.006
55Mn	0.163	181Ta	0.001
59Co	0.003	182W	0.008
60Ni	0.025	185Re	0.007
63Cu	0.04	193Ir*	0.005
65Cu	0.021	195Pt*	0.005
66Zn	0.175	197Au*	0.005
69Ga	0.014	208Pb	0.006
71Ga	0.003	209Bi	0.004
74Ge	0.027		

*Detection limit of PGE-Au determined using PGE-doped Fe-sulfide standard (Po727: see Dare et al. 2011). GSE-1g is not suitable for PGE-Au.

Table 2: Results of the analysis of reference materials used in the calibration of laser ablation ICP-MS and to monitor the quality of the data. All element concentrations are given in ppm. Elements measured but not detected in the Fe-oxides (Ru, Pd, Re, Ir, Pt, Au and Bi) are not shown.

Isotope	**Detection Limit** in ppm (33 um beam)	**CALIBRATION** **Reference Material**	Certificate Value		**MONITOR GSD** Certificate Value		This study		**MONITOR GOR-128g** Working value			This study		**MONITOR BC28** [1]Working value	This study	
			ave	std	ave	std±	ave (n=68)	std	ave	std	Source	ave (n=15)	std	ave	ave (n=78)	std
24Mg	0.10	**GSE**	21106	181	21709	241	**21834**	500	156826	1810	Cert.	**140050**	11167	11618	**10218**	1421
27Al	2.00	**GSE**	68804	2117	70922	1588	**72006**	5545	52446	900	Info.	**46971**	1472	20787	**17528**	2833
31P	15	**GSD**	860	160	Used in calibration				N.A.			**94**	7	N.A.	**46**	33
45Sc	0.40	**GSE**	530	20	52	2	**57**	5	32.1	1.1	Cert.	**36**	2	31	**30**	10
47Ti	1.00	**GSE**	450	42	7432	360	**7941**	322	1727	72	Cert.	**1543**	35	87615	**73948**	7096
51V	0.20	**GSE**	440	20	44	2	**47**	2	189	13	Cert.	**176**	7	9603	**9016**	569
52Cr	3.00	**GSE**	400	80	42	3	**51**	4	2272	171	Cert.	**2070**	109	1172	**1361**	91
55Mn	2.00	**GSE**	590	20	220	20	**241**	16	1363	70	Cert.	**1293**	28	2125	**2021**	181
59Co	0.20	**GSE**	380	20	40	2	**41**	1	92.4	6.2	Cert.	**89**	4	241	**289**	26
60Ni	1.50	**GSE**	440	30	58	4	**65**	5	1074	61	Cert.	**1080**	103	573	**614**	41
63Cu	0.10	**GSE**	380	40	42	2	**49**	7	63.8	12.5	Cert.	**62**	2	33	**32**	32
65Cu	0.70	**GSE**	380	40	42	2	**50**	7	63.8	12.5	Cert.	**61**	2	33	**45**	37
66Zn	0.80	**GSE**	460	10	54	2	**61**	7	74.7	6.7	Cert.	**72**	5	588	**472**	97
71Ga	0.40	**GSE**	490	70	54	7	**55**	2	8.67	1.07	Cert.	**7.6**	0.3	*41.1*	**48**	5
74Ge	0.50	**GSE**	320	80	32	8	**34**	2	0.96		Info.	**1.0**	0.1	*0.86*	**0.88**	0.12
89Y	0.04	**GSE**	410	30	42	2	**43**	4	11.8	0.5	Cert.	**11.2**	0.4	*0.08*	**0.13**	0.10
90Zr	0.06	**GSE**	410	30	42	2	**46**	4	10	0.5	Cert.	**9.8**	0.4	*27.50*	**22.90**	4.90
92Zr	0.20	**GSE**	410	30	42	2	**45**	2	10	0.5	Cert.	**6.1**	0.3	*11.66*	**12.99**	2.65
93Nb	0.10	**GSE**	420	40	42	3	**44**	2	0.099	0.007	Cert.	**0.09**	0.01	*1.72*	**1.57**	0.20
95Mo	0.60	**GSE**	390	30	39	3	**41**	2	0.71	0.26	Cert.	**0.67**	0.15	*0.76*	**0.83**	0.36
118Sn	0.20	**GSE**	280	50	29	6	**31**	3	N.A.			**1.98**	0.56	*2.20*	**4.09**	4.22
139La	0.03	**GSE**	392	4	39	0.4	**41**	3	N.A.			**0.12**	0.01	N.A.	**0.02**	0.02
147Sm	0.20	**GSE**	488	5	48	0.5	**50**	4	N.A.			**0.52**	0.03	N.A.	**0.01**	0.04
172Yb	0.06	**GSE**	520	5	51	0.5	**53**	5	N.A.			**1.33**	0.09	N.A.	**0.01**	0.01
178Hf	0.10	**GSE**	395	7	39	2	**43**	4	0.349	0.017	Cert.	**0.33**	0.02	*0.58*	**0.88**	0.19
181Ta	0.05	**GSE**	390	40	40	4	**41**	3	0.019	0.001	Cert.	**0.02**	0.00	*0.07*	**0.15**	0.06
182W	0.10	**GSE**	430	50	43	4	**46**	3	15.5	2.4	Info.	**15.07**	0.61	*0.51*	**0.25**	0.26
208Pb	0.05	**GSE**	378	12	50	2	**55**	5	N.A.			**0.73**	0.23	*1.98*	**2.11**	2.29

^{57}Fe was used as the internal standard using the following values: 9.8 wt.% (GSE), 10.3 wt.% (GSD), 7.6 wt.% (GOR-128g) and 57.2 wt.% (BC28)

[1] Working values BC28, a natural magnetite from the Bushveld Complex (Barnes et al. 2004), taken from Dare et al. (2013): whole rock INAA data recalculated to 100% magnetite by a factor of 1.07. Informational values (in grey italics) from LA-ICP-MS, for most elements except Hf and Ta by INAA, determined using independant calibration by MASS-1, BCR-2g and NIST361 (after Dare et al., 2012)

Abbreviations: Ave - average, Std -standard deviation, Cert.- certificate values, Info - Informational values from certifcate

Table 3: List of minerals analyzed by laser ablation ICP-MS (LA-ICP-MS) and by electron microprobe (EMP). Full analytical results are given in Appendices 2 and 3. Average LA-ICP-MS results are given in Tables 4-8.

	No. of Analyses	
Mineral	**LA-ICP-MS**	**EMP**
Magnetite	225	200
Ilmenite	458	418
Chromite		3
Olivine	125	132
Plagioclase		219
Clinopyroxene		84
Orthopyroxene		49
Biotite		102
Apatite		38
Sulfide		48
Total n=	808	1293

Table 4: Average composition of ilmenite (concentration in ppm) by LA-ICP-MS analysis from Sudbury Igneous Complex (Fertile areas above mineralized embayments)

Analysis No.	**Location**	**Rock Type**	**Mineral**	**N**	**24Mg**	**27Al**	**45Sc**	**47Ti**	**51V**	**52Cr**	**55Mn**	**59Co**	**60Ni**	**63Cu**
			DL 33-75 um		0.01 - 0.1	0.5-2.0	0.1 - 0.4	0.2 - 1.0	0.06 - 0.2	0.07 - 3.0	0.7 - 2.2	0.05 - 0.2	0.4 - 1.6	0.04 - 0.1
Fertile_Sudbury Igneous Complex														
99AV466	Creighton Hwy 144	TZG	Ilmenite	6	375	13	9.3	296418	347	14	15464	33	0.7	2.48
99AV11	Creighton Hwy 144	TZG	Ilmenite	3	598	41	20.8	291264	343	9	14200	25	4.3	4.78
99AV12	Creighton Hwy 144	TZG	Ilmenite	4	764	49	5.0	279951	1066	48	13280	39	8.1	4.49
01AV463	Creighton Hwy 144	TZG	Ilmenite	4	673	132	20.6	291660	2457	133	13193	59	4.7	4.55
99AV13	Creighton Hwy 144	Norite	Ilmenite	5	1298	59	15.3	265868	2843	1550	6424	59	12.4	2.05
99AV26	Creighton Hwy 144	Norite (Mg-rich)	Ilmenite	3	1203	32	18.2	292004	926	261	8741	52	8.7	2.71
99AV29	Creighton Hwy 144	Norite (Mg-rich)	Ilmenite	6	2320	163	81.9	235542	3377	919	4708	90	31.3	2.50
99AV30	Creighton Hwy 144	Norite (Mg-rich)	Ilmenite	5	2478	455	98.4	269236	4913	1272	3823	119	61.8	5.03
99AV34	Creighton Hwy 144	Norite	Ilmenite	5	880	9	36.2	302161	441	190	15079	50	7.7	3.30
99AV38	Creighton Hwy 144	Norite	Ilmenite	5	924	20	30.4	325796	220	48	32552	46	5.5	2.44
99AV44	Creighton Hwy 144	Norite	Ilmenite	4	844	15	31.9	292381	202	100	22179	48	7.5	2.48
99AV46	Creighton Hwy 144	Norite (Mg-rich)	Ilmenite	3	791	9	36.7	285005	228	83	18398	51	4.4	2.41
99AV59	Creighton Hwy 144	Norite	Ilmenite	5	2382	795	76.1	283588	2910	1836	4158	111	30.9	4.92
99AV68	Creighton Hwy 144	Norite	Ilmenite	6	1024	50	22.9	313905	223	335	17302	43	9.0	4.35
99AV79	Creighton Hwy 144	Basal norite	Ilmenite	5	1306	19	6.5	318778	165	82	24122	43	9.9	3.41
01AV309	Creighton Hwy 144	Basal norite	Ilmenite	7	1461	57	30.8	347417	262	251	17901	47	30.2	4.99
01AV310	Creighton Hwy 144	Basal norite	Ilmenite	5	1319	66	31.2	310702	202	213	18391	46	21.7	3.04
CRTN1	Gertrude Mine	Diss. Ore (Sublayer)	Ilmenite	3	1538	69	7.3	282877	290	348	20079	32	39.6	3.23
CRTN2	Gertrude Mine	Diss. Ore (Sublayer)	Ilmenite	3	602	1157	26.2	270754	1386	5958	30773	16	20.4	1.68
13AV372132	Levack embayment	Granophyre	Ilmenite	4	207	10	12.8	334883	66	10	14481	16.7	0.5	1.05
13AV372133	Levack embayment	TZG	Ilmenite	5	363	9	50.3	329852	1299	6	11150	41.1	0.6	0.99
13AV372135	Levack embayment	TZG	Ilmenite	4	364	48	21.8	307496	2181	22	14355	40.1	5.1	1.24
13AV372137	Levack embayment	TZG	Ilmenite	3	441	35	34.3	309493	2078	70	18374	30.4	3.2	1.16
13AV372138	Levack embayment	Felsic Norite	Ilmenite	2	350	20	36.7	300324	943	40	21271	35.9	3.9	1.39
01AV449	Levack	TZG	Ilmenite	3	288	37	40.2	266518	3298	5	14510	50.7	0.3	1.07
98AV22	Levack	Felsic Norite	Ilmenite	5	693	380	125.3	256987	2627	894	19088	45.7	18.0	3.82
98AV15	Levack	Felsic Norite	Ilmenite	4	511	24	117.5	259808	2136	340	17873	43	9.0	2.94
98AV16	Levack	Felsic Norite	Ilmenite	4	324	462	125.5	231497	1859	1219	18217	11.9	13.9	2.51
98AV17	Levack	Mafic Norite	Ilmenite	4	2822	331	99.2	256877	3018	7472	14959	64.4	130.8	2.73
98AV18	Levack	Mafic Norite	Ilmenite	5	1317	334	118.6	255252	2926	7551	19914	39.6	66.5	2.68
98AV11	McCreedy East	Mafic Norite	Ilmenite	6	2200	265	142.2	255362	2758	6649	17417	59.5	97.7	3.15
99AV118	Levack	Diss ore	Ilmenite	2	1156	1135	76.6	247251	990	3863	43088	42.3	187.0	1.96
01AV19	Levack	Diss ore	Ilmenite	2	514	583	70.3	217831	1167	1179	26745	28.0	36.0	1.58
02AV884A	Victor	Sublayer Norite	Ilmenite	5	394	19	24.2	274650	951	235	24437	29.8	13.1	1.01
00AV306A	Worthington Offset	IQD (quench)	Ilmenite	3	616	10	6.7	263200	41	23	20190	21.1	41.3	2.95
11AV300B	Worthington Offset	IQD	Ilmenite	7	1223	9	9.5	285384	210	365	24457	20.5	51.0	1.11
11AV300B	Worthington Offset	IQD	Ilmenite in s	*4*	1275	5	8.8	283187	206	374	22577	25.7	69.6	1.18
11AV300B	Worthington Offset	IQD	Ilmenite in s	*3*	1154	13	10.4	288314	215	353	26964	13.6	26.3	1.02
SDW2A	Worthington Offset	IQD	Ilmenite	5	578	20	7.5	288574	91	32	25013	21.8	41.8	1.29

Abbreviations: N = Number of analyses; DL = detection limit for a range of beam sizes; TZG - Transition Zone Gabbro (Middle Unit); IQD - Inclusion-bearing quartz diorite; Diss. - disseminated
CRTN1 and 2 samples are from Dare et al. 2010

Table 4 cont: Average composition of ilmenite (concentration in ppm) by LA-ICP-MS analysis from Sudbury Igneous Complex (Fertile areas above mineralized embayments)

Analysis No.	66Zn	71Ga	74Ge	89Y	92Zr	93Nb	95Mo	118Sn	139La	147Sm	172Yb	178Hf	181Ta	182W	208Pb
	0.2 - 0.8	0.1 - 0.4	0.15 -0.5	0.01 - 0.04	0.05 - 0.18	0.02 - 0.08	0.15 - 0.5	0.05 - 0.17	0.01 - 0.03	0.03 - 0.2	0.02 - 0.06	0.01 - 0.08	0.01 - 0.04	0.015 - 0.1	0.02 - 0.04
Fertile_Sudbury Igneous Complex															
99AV466	113	0.11	0.12	0.46	2.7	251	3.3	0.5				0.26	15.53	2.85	0.22
99AV11	205	0.56	0.19	0.79	3.6	193	3.3	0.6				0.28	12.00	3.15	1.27
99AV12	185	1.36	0.17	0.38	1.5	181	3.6	0.7				0.32	10.32	1.42	0.58
01AV463	172	0.80	0.10	0.34	1.3	275	1.2	1.5				0.12	17.70	3.54	4.28
99AV13	100	3.27	0.16	0.44	1.1	454	1.7	0.8				0.03	20.23	3.40	0.37
99AV26	105	0.21	0.18	0.45	3.3	706	1.4	0.5				0.03	31.86	2.20	0.26
99AV29	152	6.92	0.25	0.57	5.2	479	7.1	28.2	0.29	0.09	0.07	0.09	21.06	2.94	0.20
99AV30	260	10.47	0.20	0.31	4.1	439	5.6	27.8				0.08	20.20	2.55	0.61
99AV34	123	0.15	0.12	1.02	2.6	497	5.8	0.5	0.02	0.11	0.02	0.01	27.35	4.65	4.67
99AV38	125	0.56	0.28	0.92	1.6	452	3.3	3.1				0.26	29.15	5.50	3.31
99AV44	154	0.90	0.35	0.54	1.7	476	12.1	0.7	0.02	0.14	0.02	0.08	26.27	3.57	3.51
99AV46	118	0.38	0.37	0.73	1.9	479	4.2	0.5	0.02	0.16	0.18	0.09	27.60	2.16	0.59
99AV59	297	5.83	0.13	0.18	2.4	436	5.9	25.1				0.08	20.31	2.74	0.35
99AV68	212	0.32	0.14	0.12	3.8	551	3.1	0.7				0.10	28.08	4.58	2.70
99AV79	173	0.14	0.14	0.34	2.0	542	5.4	0.5				0.03	23.61	3.75	0.80
01AV309	138	0.61	0.17	0.36	6.7	642	9.6	1.1				0.18	34.53	9.58	1.83
01AV310	80	0.43	0.13	0.29	2.9	561	2.1	0.8				0.06	28.90	4.86	0.69
CRTN1	127	0.27	0.17	0.82	1.8	517	4.3	0.9	0.02	0.08	0.02	0.31	24.03	5.25	2.36
CRTN2	767	1.43	0.34	0.75	2.2	655	5.6	9.0	0.03	0.08	0.02	0.10	39.14	10.62	0.53
13AV372132	68.2	0.15	0.24	0.87	376.2	415	13.5	1.0	0.03	0.07	0.37	17.39	17.10	0.95	0.04
13AV372133	124.6	0.12	0.25	0.41	232.8	157	4.8	3.8	0.01	0.08	0.16	16.53	7.81	0.55	0.04
13AV372135	96.3	0.27	0.20	0.31	63.4	458	4.6	4.2	0.04	0.03	0.16	5.79	16.72	4.29	0.08
13AV372137	119.7	0.33	0.16	0.45	246.7	514	6.6	6.5	0.05	0.03	0.25	12.64	14.51	1.54	0.03
13AV372138	33.6	0.40	0.15	0.59	334.0	530	7.7	8.3	0.05	0.03	0.39	14.38	15.14	2.16	0.20
01AV449	120.9	0.17	0.14	1.03	549.4	323	6.1	3.2	0.16	0.03	0.57	21.79	12.26	1.19	0.21
98AV22	237.0	1.66	0.27	2.15	539.6	454	11.9	38.6	0.04	0.03	1.50	36.90	20.40	1.99	0.62
98AV15	123	0.55	0.32	1.39	302.9	560	14.6	34.0	0.02	0.11	0.94	20.20	25.70	2.48	1.54
98AV16	45.6	1.52	0.39	1.12	157.1	464	9.4	32.5	0.25	0.10	0.36	25.28	23.09	2.96	1.88
98AV17	265.2	2.63	0.36	1.23	284.3	308	7.0	16.3	0.03	0.04	0.29	37.62	14.26	0.98	0.49
98AV18	329.4	2.13	0.36	1.40	225.4	336	6.0	36.4	0.19	0.09	0.33	36.88	16.20	0.88	1.13
98AV11	207.4	2.38	0.33	0.92	64.5	513	6.5	38.3	0.09	0.08	0.37	6.58	19.49	1.04	0.19
99AV118	199.7	6.98	0.14	0.80	186.1	187	4.9	17.1	0.10	0.01	0.27	27.09	9.08	0.64	0.28
01AV19	267.1	2.92	0.25	0.58	200.6	538	5.8	32.3	0.15	0.07	0.21	23.42	19.01	4.19	0.39
02AV884A	192.6	0.24	0.15	0.63	454.9	168	4.9	3.9	0.02	0.03	0.25	19.08	8.94	2.59	0.04
00AV306A	53	0.05	0.10	0.64	0.8	240	4.0	0.1	0.02	0.03	0.02	0.00	13.93	1.49	0.40
11AV300B	60	0.08	0.11	0.42	0.6	621	3.8	0.4	0.02	0.03	0.02	0.01	36.74	10.49	0.07
11AV300B	79	0.07	0.13	0.39	0.6	639	3.6	0.3	0.02	0.03	0.02	0.01	37.53	5.56	0.09
11AV300B	35	0.10	0.09	0.47	0.5	595	4.0	0.4	0.02	0.03	0.02	0.02	35.69	17.05	0.05
SDW2A	117	0.05	0.45	0.44	0.2	289	3.1	0.6	0.02	0.03	0.02	0.00	24.37	1.57	0.11

Abbreviations: N = Number of analyses; DL = detection limit for a range of beam sizes; TZG - Transition Zone Gabbro (Middle Unit); IQD - Inclusion-bearing quartz diorite; Diss. - dissemina
CRTN1 and 2 samples are from Dare et al. 2010

Table 4b: Average composition of ilmenite (concentration in ppm) by LA-ICP-MS analysis from Sudbury Igneous Complex ("Barren" areas away from mineralized embayments)

Analysis No.	Location	Rock Type	Mineral	N	24Mg	27Al	45Sc	47Ti	51V	52Cr	55Mn	59Co	60Ni	63Cu
			DL 33-75 um		0.01 - 0.1	0.5-2.0	0.1 - 0.4	0.2 - 1.0	0.06 - 0.2	0.07 - 3.0	0.7 - 2.2	0.05 - 0.2	0.4 - 1.6	0.04 - 0.1
"Barren"_Sudbury Igneous Complex														
11AV115	Gertrude Echo	TZG	Ilmenite	5	593	9	8.0	299756	357	10	19022	29	0.6	3.82
11AV104	Gertrude Echo	TZG	Ilmenite	5	801	16	3.2	275696	969	22	13224	32	6.3	2.58
11AV141	Abandoned Rwy	TZG	Ilmenite	5	864	12	3.1	289193	1248	28	17007	40	4.6	1.99
11AV105	Gertrude Echo	TZG	Ilmenite	3	674	15	4.6	238766	705	54	14206	31	3.6	1.70
11AV107	Gertrude Echo	TZG	Ilmenite	5	870	19	2.7	264366	767	21	12841	29	11.6	1.78
11AV139	Abandoned Rwy	TZG	Ilmenite	3	1492	37	11.6	268425	344	15	17906	58	5.7	4.47
11AV112	Gertrude Echo	TZG	Ilmenite	5	725	25	2.9	276019	355	532	14769	46	6.2	3.86
11AV101	Gertrude Echo	TZG	Ilmenite	5	1198	29	4.0	288171	430	1283	15683	53	8.9	3.27
11AV137	Abandoned Rwy	Norite	Ilmenite	4	1007	19	9.5	263027	371	439	27148	47	7.1	4.96
11AV135	Abandoned Rwy	Norite	Ilmenite	3	1288	23	11.6	290864	330	328	24598	51	10.9	4.08
11AV133	Abandoned Rwy	Norite	Ilmenite	6	1472	27	9.8	323924	335	152	23620	52	9.5	3.79
11AV129	Abandoned Rwy	Norite	Ilmenite	3	1122	21	9.2	272625	415	353	23194	56	6.6	4.49
11AV125	Abandoned Rwy	Norite	Ilmenite	4	1524	17	10.3	295160	158	119	23441	45	9.2	4.23
11AV122	Abandoned Rwy	Basal norite	Ilmenite	7	1318	19	8.5	325016	224	93	25291	43	8.8	3.30
11AV120	Abandoned Rwy	Basal Norite	Ilmenite	5	688	57	45.7	233464	3315	1911	19883	41	11.9	4.89
12AV20	Windy Lake	Tonalite dike	Ilmenite	4	297	98	50.9	235901	1406	4	10240	50	0.6	1.39
12AV25	Windy Lake	TZG	Ilmenite	3	335	10	49.7	243572	1582	4	10496	60	0.6	1.37
12AV28	Windy Lake	TZG	Ilmenite	4	332	69	58.9	236342	1706	3	10418	64	0.8	1.43
12AV30	Windy Lake	TZG	Ilmenite	4	310	89	54.5	231290	2014	9	9103	51	1.0	1.51
12AV33	Windy Lake	TZG	Ilmenite	4	345	92	62.6	230479	2123	13	8404	64	1.7	1.58
12AV35	Windy Lake	TZG	Ilmenite	4	463	38	61.6	235015	2334	11	9446	68	2.3	1.73
11AV155	Cascaden	Felsic Norite	Ilmenite	4	454	39	60.3	290998	1136	28	19716	36	7.1	3.12
11AV159	Cascaden	Felsic Norite	Ilmenite	5	488	72	70.8	284694	2172	124	19162	44	6.1	4.87
11AV160	Cascaden	Felsic Norite	Ilmenite	4	555	117	87.7	276999	2524	204	15320	50	6.1	2.74
11AV162	Cascaden	Felsic Norite	Ilmenite	4	601	46	61.7	262877	2256	168	19821	45	6.0	3.15
11AV163	Cascaden	Felsic Norite	Ilmenite	3	535	54	62.5	244999	1398	113	18336	48	7.1	1.28
11AV164	Cascaden	Felsic Norite	Ilmenite	3	495	61	78.1	240110	2043	856	27006	46	10.9	3.90
11AV166	Cascaden	Basal norite	Ilmenite	3	485	118	58.6	289698	1594	248	20500	46	9.4	4.69
01AV256	Worthington Offset	QD	Ilmenite	5	944	5	11.8	278452	226	147	20438	45.6	22.1	1.17
01AV257	Worthington Offset	QD (quench)	Ilmenite	2	948	8	8.1	274564	89	32	23589	42.3	7.5	1.09
01AV261	Worthington Offset	QD	Ilmenite	6	858	7	8.9	285824	83	68	18730	41.5	14.1	0.87

Abbreviations: N = Number of analyses; DL = detection limit for a range of beam sizes; TZG - Transition Zone Gabbro (Middle Unit); QD - quartz diorite; Diss. - disseminated

Table 4b cont: Average composition of ilmenite (concentration in ppm) by LA-ICP-MS analysis from Sudbury Igneous Complex ("Barren" areas away from mineralized embayments)

Analysis No.	**66Zn**	**71Ga**	**74Ge**	**89Y**	**92Zr**	**93Nb**	**95Mo**	**118Sn**	**139La**	**147Sm**	**172Yb**	**178Hf**	**181Ta**	**182W**	**208Pb**
	0.2 - 0.8	0.1 - 0.4	0.15 -0.5	0.01 - 0.04	0.05 - 0.18	0.02 - 0.08	0.15 - 0.5	0.05 - 0.17	0.01 - 0.03	0.03 - 0.2	0.02 - 0.06	0.01 - 0.08	0.01 - 0.04	0.015 - 0.1	0.02 - 0.04
"Barren"_Sudbury Igneous Complex															
11AV115	186	0.13	0.08	0.44	1.7	236.0	4.2	0.5				0.09	13.65	3.60	0.15
11AV104	216	0.68	0.16	0.37	0.8	186.0	2.4	0.4				0.04	12.22	1.77	0.38
11AV141	158	0.18	0.10	0.38	0.2	224.3	2.0	0.2				0.02	17.17	2.86	0.18
11AV105	161	0.73	0.23	0.17	0.4	131.1	1.8	0.5	0.01	0.07	0.02	0.18	7.96	1.50	0.17
11AV107	154	0.93	0.11	0.36	0.9	161.5	2.5	0.7				0.03	10.26	3.04	0.43
11AV139	192	0.30	0.08	0.39	4.1	488.9	6.4	0.5	0.02	0.01	0.01	0.15	22.85	3.12	0.18
11AV112	196	0.93	0.10	0.38	0.8	206.2	2.1	0.3				0.03	10.59	2.89	0.40
11AV101	159	1.17	0.17	0.31	0.8	186.1	2.7	0.3				0.10	9.71	2.67	0.17
11AV137	87	0.23	0.14	0.34	1.0	276.2	2.6	0.3	0.02	0.01	0.01	0.01	11.07	2.32	0.08
11AV135	146	0.20	0.17	0.38	2.1	364.9	3.4	0.3	0.01	0.01	0.01	0.01	16.02	2.05	0.02
11AV133	127	0.24	0.09	0.45	0.5	445.1	3.5	0.3				0.29	23.63	3.76	1.73
11AV129	164	0.24	0.14	0.35	1.8	354.8	4.7	0.3	0.02	0.01	0.01	0.02	15.15	2.92	0.11
11AV125	173	0.18	0.15	0.36	2.7	477.2	3.4	0.3	0.02	0.01	0.01	0.01	22.71	1.76	0.06
11AV122	191	0.19	0.15	0.28	1.9	634.7	8.5	0.5				0.08	28.30	5.51	0.39
11AV120	102	2.99	0.18	0.89	3.2	439.5	5.7	19.5	0.14	0.01	0.33	0.01	17.31	2.65	0.14
12AV20	199	0.62	0.19	0.75	391.7	147	6.0	7.4	0.02	0.06	0.65	17.40	8.44	1.73	0.06
12AV25	145	0.52	0.20	0.43	344.0	132	5.3	5.0	0.02	0.06	0.50	16.68	7.72	1.63	0.06
12AV28	194	1.05	0.19	0.51	324.6	131	4.9	4.5	0.02	0.04	0.46	16.12	7.62	1.37	0.04
12AV30	123	1.73	0.21	0.52	403.4	110	4.0	5.1	0.02	0.06	0.54	15.72	6.63	0.97	0.05
12AV33	84	2.26	0.25	0.46	378.4	77	3.3	3.7	0.02	0.06	0.38	15.30	4.84	1.04	0.03
12AV35	90	1.82	0.22	0.57	308.9	69	2.8	3.1	0.01	0.07	0.36	12.33	4.46	0.73	0.10
11AV155	97	0.37	0.31	0.91	348.8	530	14.9	21.2				23.13	19.80	1.91	0.15
11AV159	107	0.37	0.25	0.98	325.3	537	14.5	18.1				21.81	23.86	2.46	0.03
11AV160	156	0.42	0.20	1.16	221.8	541	13.1	24.5	0.02	0.01	1.62	21.19	25.04	2.46	0.05
11AV162	132	0.34	0.16	1.40	444.4	546	12.1	16.5	0.02	0.01	1.85	32.23	24.78	2.50	0.07
11AV163	183	0.59	0.21	0.96	164.6	531	12.1	20.6	0.01	0.06	0.92	12.81	21.97	2.19	0.04
11AV164	162	0.42	0.16	1.22	355.0	517	13.4	30.3	0.02	0.01	1.16	33.98	21.52	2.28	0.20
11AV166	117	1.19	0.21	1.00	160.4	593	12.9	20.0				12.72	21.88	2.71	0.83
01AV256	103	0.06	0.10	0.42	2.1	399	6.3	0.2	0.02	0.03	0.02	0.01	25.59	3.48	0.11
01AV257	170	0.04	0.13	0.49	3.9	502	9.4	0.2	0.02	0.03	0.02	0.00	43.41	33.37	0.05
01AV261	61	0.07	0.07	0.43	2.8	193	8.0	0.2	0.02	0.03	0.02	0.00	13.69	0.86	0.13

Abbreviations: N = Number of analyses; DL = detection limit for a range of beam sizes; TZG - Transition Zone Gabbro (Middle Unit); QD - quartz diorite; Diss. - disseminated

Table 5: Average composition of ilmenite (concentration in ppm) by LA-ICP-MS analysis from Nain Plutonic Suite

Analysis No.	Location	Rock Type	Mineral	N	24Mg	27Al	45Sc	47Ti	51V	52Cr	55Mn	59Co	60Ni	63Cu
			DL 33-75 um		0.01 - 0.1	0.5-2.0	0.1 - 0.4	0.2 - 1.0	0.06 - 0.2	0.07 - 3.0	0.7 - 2.2	0.05 - 0.2	0.4 - 1.6	0.04 - 0.1
Fertile_Nain Plutonic Suite (Eastern Deeps, Voisey's Bay deposit)														
C96-2531	VB266 -Eastern Deeps	NTT (S poor)	Ilmenite	5	24279	188	55.9	288160	1239	938	3377	151	270.4	1.35
C96-2532	VB266 -Eastern Deeps	NTT (S poor)	Ilmenite	6	13863	79	175.4	229505	411	526	2570	112	195.9	6.26
C96-2533	VB266 -Eastern Deeps	NTT (S poor)	Ilmenite	4	21788	115	46.5	286769	1177	853	3291	161	280.4	1.23
C97-1104	VB266 -Eastern Deeps	VTT (S-poor)	Ilmenite	4	29427	79	212.2	231656	1115	1471	2487	149	347.3	6.23
C96-2542	VB266 -Eastern Deeps	VTT (S-poor)	Ilmenite	5	26005	622	36.2	286254	959	906	3372	172	332.8	1.19
C96-2554	VB266 -Eastern Deeps	VTT (S-rich 5%)	Ilmenite	5	11503	98	8.4	294247	518	397	4069	26	64.1	1.31
C96-2555	VB266 -Eastern Deeps	VTT (S-rich)	Ilmenite	5	9630	374	43.0	284522	441	440	5193	48	71.7	4.22
C96-2556	VB266 -Eastern Deeps	Syenite (no S)	Ilmenite	4	527	177	34.5	280008	112	15	9570	67	19.2	2.20
C97-0757	VB254 -Eastern Deeps	Ol gabbro (S poor)	Ilmenite	3	8437	616	27.4	252135	980	714	3543	97	46.2	4.27
C97-0706	VB254 -Eastern Deeps	Ol gabbro (S poor)	Ilmenite	4	9853	221	65.8	262680	1140	520	3525	110	41.3	2.51
C97-0701	VB254 -Eastern Deeps	Ol gabbro (S poor)	Ilmenite	4	14578	29	217.8	248693	909	275	2914	104	85.3	6.61
C97-0756	VB254 -Eastern Deeps	Ol gabbro (S poor)	Ilmenite	5	7612	185	66.4	291605	650	345	4574	192	173.6	2.10
C97-0696	VB254 -Eastern Deeps	NTT (S poor)	Ilmenite	5	13951	79	18.0	292628	421	112	4067	133	119.1	1.52
C97-0689	VB254 -Eastern Deeps	VTT (S-poor)	Ilmenite	6	19709	109	33.0	289303	778	1167	3801	99	137.4	1.50
C97-0692	VB254 -Eastern Deeps	VTT(S-rich 5%)	Ilmenite	5	16662	177	33.5	280330	962	639	3385	57	178.6	1.59
C97-0683	VB254 -Eastern Deeps	VTT (S-rich)	Ilmenite	2	9646	206	28.4	279262	557	88	6874	26	79.8	3.86
C96-2571	VB254 -Eastern Deeps	Melatroctolite (fragment	Ilmenite	5	21725	133	23.1	361112	548	1447	4109	74	133.7	1.34
C97-0673	VB254 -Eastern Deeps	VTT or Chilled Dike Margi	Ilmenite	5	7387	240	19.3	288310	427	86	6068	123	63.1	2.24
VB7	Ovoid	ol gb 'leopard troctolite'	Ilmenite	4	6103	280	14.5	327418	464	176	8464	26	87.0	32.31
Barren_Nain Plutonic Suite (Newark Island Layered Intrusion)														
13AV4434	Hybrid Series	gabbro	Ilmenite	5	2610	153	52.3	254925	1148	63	5109	132	51.7	1.55
13AV4551	Trough C	gabbro	Ilmenite	6	563	188	51.1	265305	598	27	6398	67	7.5	1.71
13AV4577	Trough C	olivine gabbro	Ilmenite	5	6021	270	62.7	261992	498	187	5151	123	54.4	1.39
13AV4584	Hybrid Series	olivine (Fa) gabbro	Ilmenite	5	1952	125	33.6	270439	468	48	4349	73	14.9	1.43
13AV4597	Trough B	olivine (Fa) gabbro	Ilmenite	5	1660	281	20.7	300567	1016	4	5163	69	8.2	1.37
RX321739	Trough B	olivine gabbro	Ilmenite	5	6737	421	58.7	245275	687	138	4478	118	65.1	1.65
RX321740	Trough B	olivine gabbro	Ilmenite	5	7224	272	56.5	255321	867	70	3678	99	45.4	1.43
RX321742	Trough B	olivine gabbro	Ilmenite	3	7638	240	50.1	261531	717	64	4512	104	51.4	1.39
13AV4602	Trough B	olivine (Fa) gabbro	Ilmenite	4	2921	234	22.1	306622	369	24	4635	63	12.3	1.38
RX321745	Upper Zone	gabbro	Ilmenite	5	5347	113	9.6	269690	449	201	5455	75	21.5	3.72
13AV4613	Upper Zone	gabbro	Ilmenite	4	677	19	10.0	310816	681	328	9726	42	8.0	1.42
13AV4614	Upper Zone	gabbro	Ilmenite	5	5683	154	47.9	305634	528	91	5053	69	16.2	1.38
RX321752	Upper Zone	gabbro	Ilmenite	5	3663	287	13.4	250533	666	54	4876	88	11.5	3.67
13AV4620	Upper Zone	Oxide-rich gabbro	Ilmenite	5	6179	267	38.5	286217	1142	91	4437	74	10.6	1.89
13AV4336	Upper Zone	Oxide-rich gabbro	Ilmenite	4	5374	251	38.3	288128	631	33	4639	75	9.7	2.18
RX321561	Upper Zone	olivine gabbro	Ilmenite	4	5646	171	43.8	275038	1189	318	5084	93	31.3	1.67
RX321560	Lower Zone	olivine gabbro	Ilmenite	4	6073	69	8.9	260640	774	466	4213	145	80.4	1.61
RX321559	Lower Zone	olivine gabbro	Ilmenite	3	5628	348	35.5	248043	424	522	5858	154	58.8	1.79

Abbreviations: N = Number of analyses; DL = detection limit for a range of beam sizes; NTT - normal troctolite; VTT - varied-textured troctolite; Ol - olivine; Fa - fayalite-rich

Table 5 cont: Average composition of ilmenite (concentration in ppm) by LA-ICP-MS analysis from Nain Plutonic Suite

Analysis No.	66Zn	71Ga	74Ge	89Y	92Zr	93Nb	95Mo	118Sn	139La	147Sm	172Yb	178Hf	181Ta	182W	208Pb
	0.2 - 0.8	0.1 - 0.4	0.15 -0.5	0.01 - 0.04	0.05 - 0.18	0.02 - 0.08	0.15 - 0.5	0.05 - 0.17	0.01 - 0.03	0.03 - 0.2	0.02 - 0.06	0.01 - 0.08	0.01 - 0.04	0.015 - 0.1	0.02 - 0.04
Fertile_Nain Plutonic Suite (Eastern Deeps, Voisey's Bay deposit)															
C96-2531	178	0.97	0.07	0.20	18.9	127.2	5.4	5.8	0.02	0.03	0.11	2.14	9.07	0.37	0.22
C96-2532	167	0.73	0.30	0.56	28.4	101.9	14.1	1.9	0.09	0.03	0.02	1.16	7.37	11.82	0.03
C96-2533	168	0.82	0.06	0.20	25.5	170.4	11.1	6.1	0.02	0.03	0.11	2.90	11.55	0.89	0.39
C97-1104	115	0.80	0.29	0.53	29.5	137.7	11.1	3.4	0.01	0.03	0.02	2.85	8.11	0.67	0.00
C96-2542	266	2.28	0.13	0.20	31.0	119.5	5.7	3.9	0.03	0.03	0.06	3.48	9.79	0.57	0.81
C96-2554	17	0.55	0.14	0.20	54.5	65.1	0.5	1.7	0.05	0.03	0.02	2.66	5.46	0.86	0.04
C96-2555	45	2.51	0.14	0.17	31.3	74.7	1.1	16.3	0.03	0.03	0.02	2.52	5.30	3.06	0.30
C96-2556	79	2.97	0.21	0.31	14.6	1270.1	20.9	14.7	0.48	0.08	0.52	0.72	44.30	3.62	0.17
C97-0757	286	2.59	0.16	0.15	39.5	93.6	7.4	3.5	0.01	0.03	0.02	3.99	6.73	0.59	1.33
C97-0706	183	2.39	0.11	0.37	33.1	107.4	7.0	7.1	0.01	0.03	1.28	3.69	7.37	0.51	1.71
C97-0701	212	0.80	0.21	0.57	27.8	116.3	6.7	3.5	0.04	0.03	0.02	1.84	6.56	0.40	0.13
C97-0756	15	1.12	0.10	0.16	39.2	19.1	1.2	3.3	0.02	0.05	0.06	3.87	1.24	0.26	0.33
C97-0696	205	0.39	0.15	0.21	10.3	157.1	6.1	4.3	0.03	0.03	0.04	1.30	11.65	1.31	0.22
C97-0689	124	0.96	0.09	0.21	32.4	124.0	6.0	2.3	0.02	0.03	0.03	2.66	8.78	0.83	0.20
C97-0692	75	0.76	0.12	0.20	24.2	73.1	1.2	13.8	0.02	0.03	0.02	3.18	4.92	0.84	0.33
C97-0683	29	1.21	0.12	0.15	25.8	122.5	1.0	11.9	0.03	0.03	0.02	2.32	5.36	8.75	0.24
C96-2571	107	0.56	0.22	0.28	24.7	77.4	1.4	1.7	0.01	0.07	0.05	2.10	6.07	0.39	0.14
C97-0673	32	1.39	0.11	0.17	46.8	49.5	2.7	6.1	0.08	0.04	0.03	3.47	3.78	2.87	0.21
VB7	37	1.01	0.09	0.12	72.5	56.0	0.5	11.9				2.43	3.11	0.27	1.40
Barren_Nain Plutonic Suite (Newark Island Layered Intrusion)															
13AV4434	87.1	2.93	0.20	0.23	19.0	345.7	12.6	19.2	0.04	0.03	0.72	1.93	24.61	11.85	0.07
13AV4551	106.6	2.36	0.19	0.35	82.7	832.5	13.7	10.1	0.31	0.04	1.00	8.11	39.00	3.28	0.09
13AV4577	40.2	2.58	0.15	0.35	146.4	92.8	3.6	7.4	0.02	0.03	1.91	13.52	5.21	1.50	0.02
13AV4584	119.4	2.10	0.17	0.39	20.8	297.8	11.3	15.8	0.21	0.03	1.83	2.17	18.40	6.22	0.05
13AV4597	115.7	4.41	0.21	0.22	14.4	46.2	2.7	3.6	0.02	0.03	0.12	1.13	2.77	0.94	0.03
RX321739	56.0	4.00	0.22	0.24	53.0	130.9	4.3	10.2	0.06	0.03	1.08	5.18	5.97	0.79	0.05
RX321740	136.0	5.56	0.23	0.38	47.9	393.4	9.7	20.4	0.06	0.03	1.77	6.71	23.04	4.30	0.04
RX321742	82.1	3.62	0.17	0.35	58.4	87.6	3.2	5.4	0.03	0.03	0.98	5.01	4.65	0.50	0.03
13AV4602	82.9	1.71	0.18	0.34	38.1	258.2	6.5	6.5	0.03	0.03	0.66	3.12	13.84	3.11	0.03
RX321745	221.9	0.67	0.15	0.16	8.9	119.0	2.0	1.5	0.03	0.04	0.01	0.75	9.92	17.22	0.05
13AV4613	101.9	0.13	0.20	0.22	6.5	145.5	6.4	1.9	0.04	0.03	0.03	0.33	7.00	24.50	0.04
13AV4614	24.2	0.85	0.15	0.21	91.8	21.0	0.8	0.6	0.02	0.03	0.07	3.53	1.21	0.03	0.03
RX321752	79.7	3.48	0.17	0.14	60.5	59.7	1.4	0.8	0.03	0.04	0.02	2.33	4.29	0.37	0.06
13AV4620	76.4	2.87	0.16	0.21	85.4	41.5	0.9	0.6	0.03	0.03	0.05	3.45	2.62	0.05	0.04
13AV4336	34.0	1.26	0.16	0.22	77.3	60.8	1.0	0.8	0.02	0.03	0.08	3.62	3.58	0.14	0.04
RX321561	96.2	1.55	0.21	0.16	60.6	28.6	1.1	0.9	0.01	0.08	0.04	2.53	1.66	0.14	0.23
RX321560	171.7	0.64	0.24	0.15	64.3	182.9	4.3	1.6	0.01	0.15	0.02	2.87	12.46	0.87	0.04
RX321559	19.3	3.04	0.15	0.15	41.5	140.9	0.9	2.9	0.03	0.10	0.02	4.93	9.43	0.71	0.03

Abbreviations: N = Number of analyses; DL = detection limit for a range of beam sizes; NTT - normal troctolite; VTT - varied-textured troctolite; Ol - olivine; Fa - fayalite-rich

Table 6: Average composition of magnetite (concentration in ppm) by LA-ICP-MS analysis from Sudbury Igneous Complex

Analysis No.	Location	Rock Type	Mineral	N	24Mg	27Al	45Sc	47Ti	51V	52Cr	55Mn	59Co	60Ni	63Cu
			DL 33-75 um		0.01 - 0.1	0.5-2.0	0.1 - 0.4	0.2 - 1.0	0.06 - 0.2	0.07 - 3.0	0.7 - 2.2	0.05 - 0.2	0.4 - 1.6	0.04 - 0.1
Fertile_Sudbury Igneous Complex														
01AV463	Creighton Hwy 144	TZG	Magnetite	3	399	2317	3.28	54859	10586	375	3203	54	31.4	2.8
99AV29	Creighton Hwy 144	Norite (Mg-rich)	Magnetite	1	692	870	1.19	3600	7047	10868	701	81	101	1.07
99AV30	Creighton Hwy 144	Norite	Magnetite	1	940	4747	4.48	14982	10637	16004	1090	18	148	
99AV59	Creighton Hwy 144	Norite	Magnetite	1	514	5881	3.85	16292	11655	26027	839	176	338	
13AV372132	Levack embayment	Granophyre	*Mt-alt titanite*	*6*	142	1447	2.22	118778	574	4	5747	16	0.4	0.48
13AV372133	Levack embayment	TZG	*Mt-alt titanite*	*1*	165	923	5.99	62362	5123	5	1730	30	0.5	0.49
13AV372135	Levack embayment	TZG	Magnetite	3	115	4688	0.85	78349	13545	81	4330	23	19.9	0.53
13AV372137	Levack embayment	TZG	Magnetite	4	106	2342	1.64	64692	12335	322	5038	23	14.9	1.14
13AV372138	Levack embayment	Felsic Norite	Magnetite	2	261	4769	6.28	66398	4541	92	5061	32	32.5	0.54
01AV449	Levack embayment	TZG	Magnetite	6	137	5098	4.70	93985	7206	4	6063	40	0.4	3.60
98AV22	Levack embayment	Felsic Norite	Magnetite in norite	2	323	6375	15.80	34397	6342	7470	4373	53	211	2.21
98AV15	Levack embayment	Felsic Norite	Magnetite in norite	3	363	4717	15.29	43481	6319	3756	4361	48	125	2.88
98AV16	Levack embayment	Felsic Norite	Magnetite adj sulf	4	226	5205	14.69	28416	4397	7274	3471	22	297	1.81
98AV16	Levack embayment	Felsic Norite	Magnetite in norite	6	201	5530	12.82	31963	4883	5876	3924	33	331	5.15
98AV17	Levack embayment	Mafic norite	Magnetite adj sulf	2	839	9994	10.64	31972	6038	62152	6695	42	560	5.76
98AV18	Levack embayment	Mafic norite	Magnetite adj sulf	3	483	11507	10.44	25150	6385	77410	8527	45	606	5.86
98AV11	McCreedy East	Mafic norite	Magnetite adj sulf	1	155	9077	5.06	17408	4411	92444	7601	36	250	8.92
99AV118	Levack embayment	Diss ore	Magnetite in norite	4	1319	19552	8.51	23952	3248	19828	6420	182	1963	0.55
99AV118	Levack embayment	Diss ore	Magnetite adj sulf	4	1469	20180	7.34	21144	3294	19254	6058	129	1554	0.87
99AV124	Levack embayment	Diss ore	Magnetite in norite	4	158	4761	4.25	23113	2323	1404	3100	27	790	0.67
99AV124	Levack embayment	Diss ore	Magnetite adj sulf	5	206	6878	7.33	25161	2574	691	3490	17	799	0.93
01AV19	Levack embayment	Diss ore	Magnetite in norite	5	564	9976	5.67	15943	4778	6253	2810	120	595	0.29
01AV19	Levack embayment	Diss ore	Magnetite adj sulf	5	409	6587	5.24	18344	2794	8448	3372	15	309	1.05
02AV884	Victor	Sublayer Norite	Magnetite in norite	4	99	7523	1.70	36999	5371	4005	4449	29	137	0.86
"Barren"_Sudbury Igneous Complex														
11AV141	Abandoned Rwy	TZG	Magnetite	2	179	126	0.27	46035	5394	185	3118	33	30.1	0.31
11AV105	Gertrude Echo	TZG	Magnetite	4	172	197	0.53	39201	3227	815	2743	22	16.3	7.00
12AV20	Windy Lake	TZG	Magnetite	4	125	5095	3.20	79226	5111	4	3887	38	0.7	1.15
12AV25	Windy Lake	TZG	Magnetite	3	115	3245	2.63	71657	5775	10	3595	40	0.8	1.46
12AV28	Windy Lake	TZG	Magnetite	4	151	4093	4.98	68314	6055	11	3295	52	3.8	1.68
12AV30	Windy Lake	TZG	Magnetite	4	190	4510	10.08	63125	7789	47	2697	52	3.9	1.45
12AV33	Windy Lake	TZG	Magnetite	4	285	5199	7.71	42174	9648	61	1798	69	9.3	1.86
12AV35	Windy Lake	TZG	Magnetite	5	251	6661	10.20	52934	8231	39	2240	81	10.9	1.46
11AV155	Cascaden	Felsic Norite	Magnetite	3	103	5164	6.64	49548	8380	198	3218	37	5.3	2.03
11AV163	Cascaden	Felsic Norite	Magnetite	3	178	5101	5.09	47669	6352	1463	4328	39	41.3	6.41
11AV164	Cascaden	Felsic Norite	Magnetite	4	279	6003	9.03	38059	5446	10878	5807	101	151	1.03
11AV166	Cascaden	Basal norite	Magnetite	5	175	5658	7.32	56307	8703	2535	4629	40	71.9	n.r.

Abbreviations: N = Number of analyses; DL = detection limit for a range of beam sizes; TZG - Transition Zone Gabbro (Middle Unit); Diss. - disseminated; Mt alt - magnetite altered; adj - adjacent

Table 6 cont: Average composition of magnetite (concentration in ppm) by LA-ICP-MS analysis from Sudbury Igneous Complex

Analysis No.	66Zn	71Ga	74Ge	89Y	92Zr	93Nb	95Mo	118Sn	139La	147Sm	172Yb	178Hf	181Ta	182W	208Pb
	0.2 - 0.8	0.1 - 0.4	0.15 -0.5	0.01 - 0.04	0.05 - 0.18	0.02 - 0.08	0.15 - 0.5	0.05 - 0.17	0.01 - 0.03	0.03 - 0.2	0.02 - 0.06	0.01 - 0.08	0.01 - 0.04	0.015 - 0.1	0.02 - 0.04
Fertile_Sudbury Igneous Complex															
01AV463	102	18.6	0.40	0.11	7.5	30.5	9.2	0.39				0.23	1.05	1.88	0.83
99AV29	153	53.4	0.82	0.11	6.7	6.4	7.1	2.39	0.05	0.08	0.04	0.05	0.16	0.23	0.50
99AV30	220	51.4	0.56	0.44	2.9	7.3	2.5	0.78				0.04	0.22	0.52	0.90
99AV59	714	74.0	0.78	0.13	3.8	4.1	2.8	2.60				0.02	0.21	0.14	0.97
13AV372132	212	15.0	1.3	1.40	23.20	51.17	42.3	5.94	0.25	0.07	0.15	1.20	4.16	1.91	0.33
13AV372133	30	5.5	1.0	0.35	14.36	2.03	9.9	4.02	0.37	0.07	0.05	1.88	0.08	0.35	2.45
13AV372135	805	8.8	1.0	0.06	9.61	8.18	9.9	9.19	0.00	0.03	0.03	0.71	0.65	0.13	0.85
13AV372137	1087	7.3	0.9	0.06	18.69	10.77	12.7	11.62	0.01	0.03	0.03	1.20	0.47	0.33	0.25
13AV372138	4216	20.0	0.9	0.05	12.87	5.41	14.3	13.65	0.04	0.03	0.03	0.73	0.52	0.19	0.15
01AV449	786	8.4	0.87	0.24	85.29	19.74	7.35	4.58	0.01	0.10	0.03	4.70	1.39	0.20	1.16
98AV22	1881	54.1	0.76	0.22	9.29	3.96	6.72	25.37	0.12	0.04	0.00	0.89	0.34	0.20	0.16
98AV15	2417	39.8	0.99	0.22	14.41	6.01	10.61	27.16	0.21	0.07	0.04	2.13	0.83	0.37	0.19
98AV16	2286	34.7	0.81	0.10	5.31	1.86	3.48	21.17	0.02	0.09	0.00	0.61	0.28	0.10	0.06
98AV16	3466	41.6	0.87	0.27	13.48	1.90	5.54	17.35	0.22	0.07	0.02	1.45	0.19	0.20	1.72
98AV17	6535	56.0	0.30	0.15	26.48	1.55	1.99	11.59	0.02	0.02	0.02	0.24	0.06	0.02	0.56
98AV18	7325	48.5	0.32	0.13	31.95	1.56	2.31	18.48	0.03	0.06	0.02	0.40	0.05	0.04	0.60
98AV11	13137	32.9	0.58	0.03	30.00	0.98	2.05	7.95	0.03	0.08	0.07	0.02	0.11	0.02	0.05
99AV118	1933	67.2	0.29	0.04	5.02	0.12	1.34	11.07	0.03	0.01	0.01	0.53	0.02	0.01	0.14
99AV118	2071	67.4	0.31	0.05	4.43	0.13	1.04	10.66	0.05	0.01	0.01	0.49	0.01	0.01	0.12
99AV124	3701	28.6	0.75	0.02	4.27	0.14	1.64	12.92	0.01	0.01	0.01	0.67	0.04	0.04	0.16
99AV124	5040	36.4	0.77	0.03	4.84	0.13	1.00	14.21	0.01	0.01	0.01	0.74	0.04	0.07	1.33
01AV19	1306	41.3	0.65	0.04	4.35	0.13	4.77	2.96	0.06	0.08	0.01	0.30	0.01	0.03	0.04
01AV19	3697	32.2	0.57	0.10	3.11	0.26	0.44	26.06	0.12	0.09	0.03	0.51	0.06	0.04	0.60
02AV884	5882	5.0	0.78	0.05	10.25	0.54	1.92	3.57	0.00	0.06	0.00	0.68	0.03	0.00	0.38
"Barren"_Sudbury Igneous Complex															
11AV141	59	8.6	0.33	0.08	2.6	9.3	5.4	0.10				0.02	0.32	1.08	0.24
11AV105	83	8.6	0.46	0.07	1.52	8.12	3.27	0.27	0.05	0.15	0.02	0.28	0.29	0.90	0.82
12AV20	2270	9.7	0.87	0.10	27.03	5.31	9.37	9.95	0.09	0.07	0.02	2.63	0.41	0.35	0.75
12AV25	2910	12.0	0.87	0.30	25.40	2.46	7.57	7.46	0.08	0.07	0.08	2.18	0.40	0.21	4.01
12AV28	4282	20.5	0.86	0.17	9.39	2.07	7.11	8.40	0.01	0.05	0.02	1.17	0.43	0.23	0.28
12AV30	4137	37.2	0.96	0.11	14.64	1.51	5.76	7.93	0.01	0.09	0.02	2.48	0.20	0.14	0.05
12AV33	2168	36.2	0.87	0.08	10.98	0.76	3.73	4.53	0.05	0.08	0.01	1.16	0.07	0.11	0.11
12AV35	5131	36.3	0.71	0.08	13.21	0.98	2.78	3.79	0.06	0.08	0.02	1.06	0.07	0.07	0.50
11AV155	2604	24.9	1.48	0.79	18.48	4.09	28.98	32.20				1.24	0.30	1.29	4.34
11AV163	3811	30.5	1.07	0.09	11.03	4.20	17.06	27.41	0.15	0.06	0.01	0.48	0.75	0.25	0.33
11AV164	3018	69.2	1.32	0.13	16.6	6.3	17.3	32.40	0.14	0.01	0.00	1.98	0.60	0.37	0.67
11AV166	5141	36.9	0.98	0.11	16.0	10.9	15.1	21.85				1.24	0.52	0.15	0.38

Abbreviations: N = Number of analyses; DL = detection limit for a range of beam sizes; TZG - Transition Zone Gabbro (Middle Unit); Diss. - disseminated; Mt alt - magnetite altered; adj - a

Table 7: Average composition of magnetite (concentration in ppm) by LA-ICP-MS analysis from Nain Plutonic Suite

Analysis No.	Location	Rock Type	Mineral	N	24Mg	27Al	45Sc	47Ti	51V	52Cr	55Mn	59Co	60Ni	63Cu
			DL 33-75 um		0.01 - 0.1	0.5-2.0	0.1 - 0.4	0.2 - 1.0	0.06 - 0.2	0.07 - 3.0	0.7 - 2.2	0.05 - 0.2	0.4 - 1.6	0.04 - 0.1
Fertile_Nain Plutonic Suite (Eastern Deeps, Voisey's Bay deposit)														
C97-0756	Eastern deeps	Ol gabbro (S poor)	Magnetite	5	1309	4419	2.22	7949	4512	6044	371	184	1052	0.1
C96-2555	Eastern deeps	VTT (S-rich)	Magnetite	5	3620	13403	2.46	19317	4991	12616	919	49	517	96.4
C97-0683	Eastern deeps	VTT (S-rich)	Magnetite	2	3418	13484	2.14	20937	7226	3462	1010	38	806	203.3
C97-0673	Eastern deeps	VTT or Chilled Dike M	Magnetite	5	2351	10548	1.32	16022	4056	1268	1468	120	464	10.0
C96-2556	Eastern deeps	Syenite (no S)	Magnetite	5	442	3480	1.37	6846	915	68	518	67	109	0.2
VB7	Ovoid	leopard troctolite	Magnetite	2	2228	19522	1.60	37084	8888	6657	1678	41	491	*654.4*
Barren_Nain Plutonic Suite (Newark Island Layered Intrusion)														
13AV4434	Hybrid Series	gabbro	Magnetite	6	603	4439	2.16	6649	8174	612	450	136	320	0.97
13AV4551	Trough C	gabbro	Magnetite	7	257	3890	3.90	27109	4282	311	1137	62	49	0.50
13AV4577	Trough C	olivine gabbro	Magnetite	5	3263	14632	6.33	39067	6863	4177	1192	167	293	0.34
13AV4584	Hybrid Series	olivine (Fa) gabbro	Magnetite	6	629	8332	2.63	33465	4617	648	1043	99	100	0.20
13AV4597	Trough B	olivine (Fa) gabbro	Magnetite	5	875	9138	1.97	36208	10857	34	1066	92	45	0.85
RX321739	Trough B	olivine gabbro	Magnetite	5	2770	10560	5.21	27208	6160	1884	870	144	312	2.40
RX321740	Trough B	olivine gabbro	Magnetite	4	1402	7912	3.32	16880	5011	349	675	98	227	0.43
RX321742	Trough B	olivine gabbro	Magnetite	3	3238	12971	5.52	30818	6789	2235	1096	149	316	8.40
13AV4602	Trough B	olivine (Fa) gabbro	Magnetite	5	992	8432	2.21	30810	3878	485	804	83	76	5.03
RX321745	Upper Zone	gabbro	Magnetite	6	1445	9052	1.36	26805	6879	625	1244	112	69	3.96
13AV4614	Upper Zone	gabbro	Magnetite	5	2019	11946	4.20	24025	8167	1738	876	95	110	0.31
13AV4620	Upper Zone	Oxide-rich gabbro	Magnetite	5	2325	6834	3.95	32350	11012	1107	1425	98	62	3.76
13AV4336	Upper Zone	Oxide-rich gabbro	Magnetite	5	2214	10208	4.59	44234	8712	682	1279	89	56	4.15
RX321561	Upper Zone	olivine gabbro	Magnetite	4	1473	11864	3.43	19748	14350	6053	1141	146	217	0.45
RX321559	Lower Zone	olivine gabbro	Magnetite	5	1445	10865	1.52	12426	6262	23065	1025	205	358	0.18

Abbreviations: N = Number of analyses; DL = detection limit for a range of beam sizes (33-75 um); VTT - varied-textured troctolite; Ol - olivine; Fa - fayalite-rich;

Table 7 cont: Average composition of magnetite (concentration in ppm) by LA-ICP-MS analysis from Nain Plutonic Suite

Analysis No.	66Zn	71Ga	74Ge	89Y	92Zr	93Nb	95Mo	118Sn	139La	147Sm	172Yb	178Hf	181Ta	182W	208Pb
	0.2 - 0.8	0.1 - 0.4	0.15 -0.5	0.01 - 0.04	0.05 - 0.18	0.02 - 0.08	0.15 - 0.5	0.05 - 0.17	0.01 - 0.03	0.03 - 0.2	0.02 - 0.06	0.01 - 0.08	0.01 - 0.04	0.015 - 0.1	0.02 - 0.04
Fertile_Nain Plutonic Suite (Eastern Deeps, Voisey's Bay deposit)															
C97-0756	86	70	1.08	0.11	1.41	0.02	1.01	1.16	0.21	0.05	0.04	0.04	0.01	0.05	0.14
C96-2555	1144	116	1.27	0.03	2.88	0.38	0.86	17.65	0.01	0.03	0.02	0.05	0.01	0.03	0.26
C97-0683	438	113	0.92	0.01	1.54	4.14	0.70	7.51	0.09	0.03	0.02	0.03	0.12	0.59	2.29
C97-0673	809	62	1.20	0.03	3.82	0.09	5.53	6.52	0.29	0.05	0.03	0.07	0.01	0.05	1.81
C96-2556	434	81	2.03	0.33	17.73	0.33	52.44	11.98	1.03	0.10	0.04	0.05	0.02	0.05	0.44
VB7	786	83	0.94	0.01	1.85	0.03	0.75	28.22				0.08	0.01	0.01	1.06
Barren_Nain Plutonic Suite (Newark Island Layered Intrusion)															
13AV4434	174	103	1.20	0.07	12.69	0.50	25.57	10.80	0.23	0.07	0.01	0.02	0.02	0.03	0.47
13AV4551	952	95	1.95	0.35	17.62	2.67	32.24	10.06	0.65	0.11	0.07	0.30	0.15	0.03	0.47
13AV4577	1147	110	1.50	0.31	10.48	1.40	12.21	16.53	0.05	0.06	0.29	0.70	0.05	0.03	0.07
13AV4584	1281	126	1.61	0.30	17.58	1.96	34.88	35.97	0.16	0.07	0.13	0.21	0.18	0.04	0.19
13AV4579	1166	109	1.33	0.08	5.80	0.61	11.59	7.77	0.15	0.03	0.03	0.03	0.03	0.04	0.73
RX321739	463	81	1.23	0.11	4.87	1.63	5.56	8.48	0.07	0.06	0.11	0.27	0.06	0.03	0.08
RX321740	651	138	1.58	0.14	17.61	1.88	37.44	35.78	0.15	0.07	0.06	0.15	0.08	0.04	0.06
RX321742	872	117	1.41	0.10	6.21	2.18	11.36	13.99	0.01	0.06	0.07	0.11	0.05	0.03	0.06
13AV4602	1448	76	1.06	0.14	8.43	2.10	17.10	11.06	0.23	0.03	0.03	0.04	0.09	0.07	0.66
RX321745	915	85	1.29	0.04	3.57	0.63	4.08	1.42	0.19	0.07	0.00	0.09	0.03	0.01	0.65
13AV4614	516	84	1.13	0.02	3.14	0.19	1.59	1.63	0.00	0.03	0.03	0.08	0.01	0.03	0.05
13AV4620	1414	72	1.15	0.09	3.35	0.04	1.94	1.19	0.23	0.03	0.03	0.13	0.01	0.03	0.78
13AV4336	651	79	1.16	0.07	4.28	0.67	2.66	1.66	0.06	0.03	0.03	0.22	0.03	0.03	0.64
RX321561	229	166	1.70	0.04	1.81	0.06	2.29	1.79	0.03	0.17	0.03	0.04	0.02	0.03	0.13
RX321559	114	91	0.94	0.04	3.48	0.09	2.29	3.25	0.02	0.14	0.03	0.07	0.01	0.04	0.05

Abbreviations: N = Number of analyses; DL = detection limit for a range of beam sizes (33-75 um); VTT - varied-textured troctolite; Ol - olivine; Fa - fayalite-rich;

Table 8: Average composition of olivine (concentration in ppm) by LA-ICP-MS analysis

Sample No.	Location	Rock Type	Int. Std. (Si wt. % EMP)	N	Fo (EMP)	Fo (std)	24Mg	27Al	31P	44Ca	45Sc	47Ti	51V	52Cr	55Mn	57Fe	59Co
			DL				*0.23*	*0.56*	*4.71*	*11.17*	*0.05*	*0.13*	*0.08*	*0.7*	*0.49*		*0.01*
Fertile_Nain Plutonic Suite (Eastern Deeps, Voisey's Bay deposit)																	
C96-2531	VB266	NTT (S poor)	17.9	4	74.1	0.2	222875	29	335	302	5.2	136	2.7	10.1	2377	193287	189
C96-2532	VB266	NTT (S poor)	17.9	6	73.6	0.4	225548	509	226	528	7.7	254	1.1	5.4	1623	201710	229
C96-2533	VB266	NTT (S poor)	17.9	4	74.4	0.3	223158	20	350	285	4.9	205	1.8	13.6	2348	192078	195
C97-1104	VB266	VTT (S-poor)	18.2	5	77.7	0.1	248319	526	174	655	11.5	172	3.3	14.2	1542	179911	202
C96-2542	VB266	VTT (S-poor)	17.9	5	73.2	0.3	221789	29	522	265	3.5	125	1.6	13.0	2488	200233	211
C96-2554	VB266	VTT (S-rich 5%)	17.2	5	64.9	1.1	191136	15	443	277	2.5	1691	4.4	9.3	3053	248789	187
C96-2555	VB266	VTT (S-rich)	16.8	6	58.7	0.3	167850	25	332	236	5.7	248	1.7	8.4	4089	287639	214
C97-0757	VB254	Ol gabbro	16.8	5	56.7	0.7	163132	28	171	409	4.5	31	0.4	6.0	4299	310595	210
C97-0706	VB254	Ol gabbro	16.7	7	56.4	1.1	162773	24	230	357	9.6	101	2.2	9.7	4298	308241	203
C97-0701	VB254	Ol gabbro	17.1	6	62.7	0.9	177964	478	197	652	11.8	47	2.2	14.6	2321	254605	183
C97-0696	VB254	NTT	17.4	4	67.6	0.8	198151	23	368	363	5.5	198	2.2	9.9	2926	232164	196
C97-0700	VB254	Ol gabbro	16.3	5	51.8	0.5	137944	404	197	517	15.1	27	3.1	6.7	2976	311003	138
C97-0689	VB254	VTT	17.7	4	71.1	1.1	213781	26	230	279	3.7	109	1.8	14.5	2705	209143	205
C97-0692	VB254	VTT (S-rich)	17.5	4	68.9	0.8	203896	11	255	159	3.4	157	1.5	5.5	2367	225000	186
C97-0683	VB254	VTT (S-rich)	16.9	5	60.3	0.5	170454	12	170	287	5.5	38	1.5	4.6	3727	276222	223
VB7	Ovoid (host troctolite)	Diss ore	*16.5	4	39.95		130350	36	454	228	1.7	149	1.4	5.1	5356	367406	203
Barren_Nain Plutonic Suite (Newark Island Layered Intrusion)																	
13AV-4577	Trough C	Olivine gabbro	16.1	4	48.8	0.3	132884	81	225	251	8.2	845	18.4	12.5	4740	343852	220
13AV-4584	Hybrid Series	Olivine gabbro	14.8	3	25.2	0.9	60872	34	323	282	4.6	2231	10.8	6.0	6512	451646	212
13AV4597	Trough B	Olivine (Fa) gabbro	15.1	3	28.9	0.9	73348	27	149	238	4.0	293	36.4	2.5	6848	460237	248
RX321739	Trough B	Olivine gabbro	16.4	6	52.4	0.9	142951	37	100	313	15.8	218	1.2	2.6	4330	323735	236
RX321740	Trough B	Olivine gabbro	16.5	5	51.4	1.1	141444	446	101	524	13.5	293	2.1	2.0	2990	331729	231
RX321742	Trough B	Olivine gabbro	16.5	5	54.4	1.4	151251	450	114	634	15.2	292	2.5	0.8	2842	318223	230
13AV4602	Trough B	Olivine (Fa) gabbro	14.9	5	29.1	1.7	74072	22	140	212	2.8	687	3.3	2.2	6887	437692	226
RX321561	Upper Zone	Olivine gabbro	16.3	5	51.1	0.5	143874	9	96	325	11.7	19	1.3	2.1	4360	336991	242
RX321560	Lower Zone	Olivine gabbro	16.8	5	58.3	0.4	165492	5	53	249	10.5	9	0.1	2.3	3682	290040	268
RX321559	Lower Zone	Olivine gabbro	16.9	5	61.0	0.8	171651	497	98	642	6.4	7	0.4	4.8	2273	267362	306

Abbreviations: N = Number of analyses; Fo = Mg/(Mg+Fe+Mn) determined by electron microprobe; DL = detection limit; std = standard deviation represents natural variation within thin section; NTT - normal troctolite; VTT - varied-textured troctolite; Ol - olivine; Fa - fayalite-rich

*Sample VB7 not analysed by EMP: Average Si value used for internal standard and Fo calculated from LA data

Table 8 cont.: Average composition of olivine (concentration in ppm) by LA-ICP-MS analysis

Sample No.	60Ni	60Ni (std)	63Cu	66Zn	71Ga	74Ge	89Y	92Zr	93Nb	95Mo	118Sn	121Sb	139La	147Sm	172Yb	178Hf	181Ta	182W	208Pb
DL	*0.12*		*0.09*	*0.35*	*0.03*	*0.19*	*0.005*	*0.04*	*0.01*	*0.08*	*0.10*	*0.11*	*0.003*	*0.024*	*0.021*	*0.019*	*0.005*	*0.022*	*0.018*
Fertile_Nain Plutonic Suite (Voisey's Bay deposit)																			
C96-2531	979	7	0.09	227	0.05	0.89	0.14	0.45	0.01	0.25	0.10	0.11	0.003	0.024	0.135	0.019	0.005	0.022	0.117
C96-2532	1344	29	1.97	254	0.21	1.17	0.02	0.52	0.01	0.76	0.10	0.11	0.003	0.024	0.021	0.019	0.005	0.022	0.066
C96-2533	1049	9	0.12	228	0.04	0.89	0.13	0.85	0.01	0.23	0.11	0.11	0.003	0.024	0.124	0.035	0.005	0.022	0.259
C97-1104	1370	36	2.06	236	0.21	1.29	0.11	0.67	0.01	0.90	0.10	0.11	0.003	0.024	0.021	0.019	0.005	0.022	0.018
C96-2542	1015	95	0.14	244	0.06	0.93	0.11	0.39	0.01	0.25	0.12	0.11	0.021	0.024	0.105	0.019	0.005	0.022	0.470
C96-2554	1426	80	0.11	259	0.07	0.95	0.04	0.41	0.39	0.31	0.10	0.11	0.030	0.024	0.026	0.019	0.027	0.022	0.035
C96-2555	1120	43	0.18	420	0.16	0.94	0.05	0.15	0.05	0.31	0.10	0.11	0.039	0.024	0.026	0.019	0.005	0.022	0.060
C97-0757	301	9	0.52	352	0.13	1.00	0.20	0.10	0.01	0.33	0.12	0.11	0.157	0.031	0.113	0.019	0.005	0.022	0.316
C97-0706	235	6	0.11	376	0.14	1.17	0.90	0.11	0.03	0.27	0.10	0.11	0.061	0.024	0.631	0.019	0.005	0.022	0.234
C97-0701	525	10	2.69	326	0.32	1.09	0.24	0.08	0.01	1.19	0.10	0.11	0.006	0.024	0.211	0.019	0.005	0.022	0.097
C97-0696	597	15	0.29	279	0.05	0.97	0.29	0.31	0.08	0.30	0.10	0.11	0.013	0.024	0.295	0.019	0.005	0.022	0.038
C97-0700	48	1	2.51	389	0.37	1.47	0.19	0.04	0.01	0.90	0.10	0.11	0.016	0.024	0.021	0.019	0.005	0.022	0.063
C97-0689	1078	25	0.09	307	0.06	0.91	0.04	0.11	0.02	0.26	0.10	0.11	0.003	0.024	0.045	0.019	0.005	0.022	0.099
C97-0692	1653	166	0.11	334	0.03	0.87	0.04	0.20	0.04	0.22	0.12	0.11	0.003	0.024	0.059	0.019	0.005	0.022	0.207
C97-0683	1844	106	0.36	460	0.13	0.95	0.10	0.09	0.01	0.28	0.10	0.11	0.055	0.024	0.065	0.019	0.005	0.022	0.040
VB7	864	17	0.27	456	0.07	0.84	0.01	0.24	0.01	0.53	0.12	0.11	0.017	0.024	0.013	0.019	0.005	0.022	0.664
Barren_Nain Plutonic Suite (Newark Island Layered Intrusion)																			
13AV-4577	315	6	0.10	373	0.39	1.14	1.55	1.10	0.23	0.51	0.16	0.11	0.029	0.024	1.456	0.064	0.008	0.022	0.018
13AV-4584	132	4	0.69	488	0.33	1.32	1.41	0.21	1.45	0.72	0.39	0.11	0.195	0.024	1.589	0.019	0.065	0.022	0.092
13AV4597	63	4	0.09	297	0.43	0.97	0.21	0.37	0.03	0.55	0.10	0.11	0.013	0.024	0.216	0.019	0.005	0.022	0.018
RX321739	412	9	0.21	360	0.26	1.24	0.98	0.74	0.01	0.40	0.13	0.11	0.036	0.024	0.965	0.033	0.005	0.022	0.032
RX321740	345	15	2.34	394	0.43	1.20	1.49	0.88	0.01	1.20	0.10	0.11	0.003	0.024	1.150	0.019	0.005	0.022	0.018
RX321742	422	10	2.16	354	0.43	1.24	0.84	0.62	0.01	1.38	0.10	0.11	0.003	0.024	0.755	0.019	0.005	0.022	0.018
13AV4602	104	5	0.09	373	0.12	1.06	0.50	0.11	0.50	0.57	0.10	0.11	0.028	0.024	0.416	0.019	0.023	0.022	0.018
RX321561	275	17	0.09	279	0.20	1.35	0.01	0.07	0.01	0.38	0.22	0.11	0.006	0.024	0.021	0.019	0.005	0.022	0.196
RX321560	491	5	0.19	313	0.17	1.11	0.00	0.05	0.01	0.33	0.10	0.11	0.005	0.024	0.021	0.019	0.005	0.022	0.036
RX321559	386	16	2.96	316	0.36	1.59	0.01	0.29	0.01	1.22	0.13	0.11	0.021	0.024	0.021	0.019	0.005	0.022	0.030

Abbreviations: N = Number of analyses; Fo = Mg/(Mg+Fe+Mn) determined by electron microprobe; DL = detection limit; std = standard deviation represents natural variation within thin section; NTT - normal troctolite; VTT - varied-textured troctolite; Ol - olivine; Fa - fayalite-rich

*Sample VB7 not analysed by EMP: Average Si value used for internal standard and Fo calculated from LA data