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Publications in this series have not been edited; they are released as submitted by the author.

Contribution to the Geological Survey of Canada's Targeted Geoscience Initiative 4 (TGI-4) Program (2010-2015)

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INDICATOR MINERAL SIGNATURES OF THE SISSON W-MO DEPOSIT, NEW BRUNSWICK: PART 2 TILL

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ABSTRACT

An indicator mineral case study was carried out around the Sisson W-Mo deposit, one of the largest W deposits in the world. The work was carried out as part of the Geological Survey of Canada's (GSC) Targeted Geoscience Initiative 4 (TGI-4), a collaborative federal geoscience program with a mandate to provide industry with the next generation of geoscience knowledge and innovative techniques that will result in more effective targeting of buried mineral deposits. This indicator mineral study is the first case study around a major W-Mo deposit in glaciated terrain. It is also the first indicator mineral case study in any terrain to identify a broad range of indicator minerals for this deposit type, in addition to the commonly known minerals scheelite and molybdenite.

Indicator minerals for the Sisson W-Mo deposit include the primary ore minerals scheelite, wolframite, and molybdenite, as well as secondary ore minerals chalcopyrite, joseite, native Bi, bismutite, bismuthinite, galena, sphalerite, arsenopyrite, pyrrhotite, and pyrite. Indicator minerals in 10 kg till samples clearly define glacial dispersal at least 10 km down-ice (southeast) of the deposit. The presence of coarse (0.5–2.0 mm) indicator minerals indicates proximity (<1 km) to the source. Thus, the use of heavy mineral sampling in regional exploration programs for W-Mo deposits is recommended. A 2 km spacing of surface till samples is likely sufficiently dense to detect the glacial dispersal train from the Sisson deposit, as well as its polymetallic nature.

INTRODUCTION

The use of till geochemistry for W-Mo exploration is well documented (e.g. Salminen and Hartikainen, 1986; Snow and Coker, 1987; Coker et al., 1988). In contrast to till geochemical methods, few case studies have been conducted around a significant W-Mo deposit to demonstrate its indicator mineral signature in till. The subcropping Sisson W-Mo deposit in eastern Canada provides an ideal site for testing indicator mineral methods for detecting glacial dispersal from a significant tungsten source. The Sisson deposit was chosen for this study because the deposit has the following features: (1) bedrock geology is well known; (2) the deposit subcrops and thus it was therefore exposed to glacial erosion; (3) is till covered; and (4) a till geochemical dispersal train was previously identified down-ice and thus metal-rich till should be available for sampling in this study.

This study was carried out as part of the Geological Survey of Canada's (GSC) Targeted Geoscience Initiative 4 (TGI-4), a collaborative federal geoscience program with a mandate to provide industry with the next generation of geoscience knowledge and innovative techniques that will result in more effective targeting of buried mineral deposits. The study is a collaborative effort between the GSC, the New Brunswick Department of Energy and Mines (NBDEM), Northcliff Resources Limited, and Hunter Dickinson Inc.

The purpose of this open file is to describe and interpret the raw indicator mineral data for till samples that were reported in GSC Open File 7387 (McClenaghan et al., 2013a). Indicator mineral data for mineralized and host rocks in the Sisson area are described in GSC Open File 7431 (McClenaghan et al., 2013b). Indicator mineral data for stream sediments in the Sisson area will be reported in a subsequent GSC Open File. Till matrix geochemical data have been reported in GSC Open File 7430 (McClenaghan et al., 2013c).

Location and access

The Sisson W-Mo deposit is located in west-central New Brunswick (Fig. 1) at UTM coordinates 650350E and 5136900N (NAD27) in the Coldstream NTS map area (NTS 21 J/06). It is 60 km north of Fredericton and is easily accessed by logging roads.

Geology

The Sisson deposit is a bulk tonnage W-Mo deposit that has been explored by various companies over the past 50 years. The bedrock geology of the deposit and surrounding area are described in McClenaghan et al. (2013b,c), as well as Nast and Williams-Jones (1991),

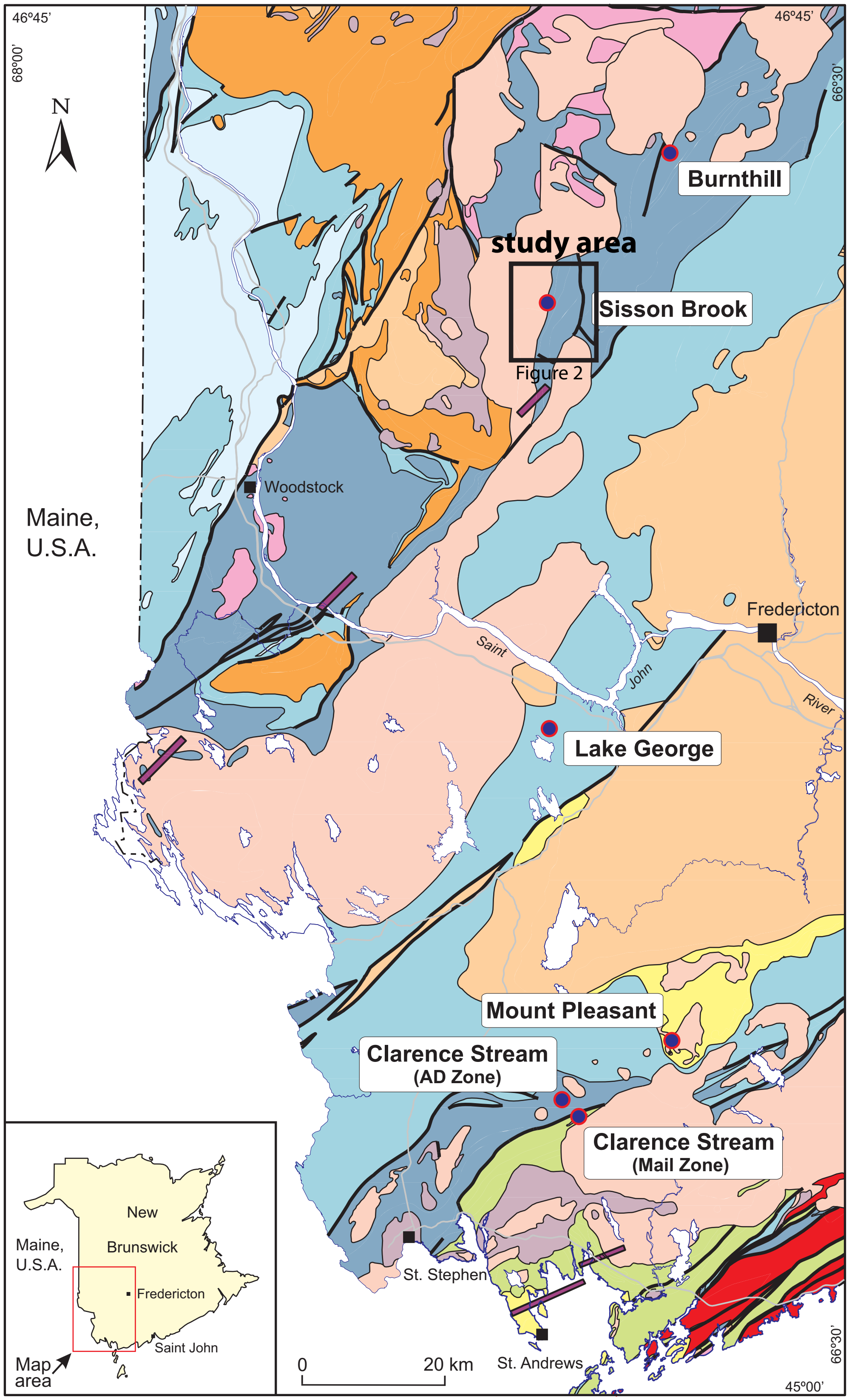


Figure 1. Bedrock geology of west-central and southern New Brunswick showing the location of the Sisson W-Mo deposit and other significant deposits (modified from Fyffe et al., 2010).

Marr (2009), Fyffe et al. (2008, 2010), and Rennie (2012). Potential indicator minerals present in the deposit are listed in Table 1. Bedrock outcrop on the Sisson property and surrounding area is rare due to the extensive cover of till, which averages approximately 8 m in thickness (Marr, 2009). Tills and their stratigraphic relationships and characteristics, and glacial transport directions are described in detail in

Table 1. Potential indicator minerals of the Sisson W-Mo deposit (from Nast and Williams-Jones 1991; Marr, 2009) in bedrock and in till samples from this study (McClenaghan et al., 2013a). PTS – polished thin section, HMC – heavy mineral concentrate.

Mineral	Formula	Specific gravity	Hardness	Presence in bedrock reported by others	Size range in PTS in this study (mm)	Size range in bedrock HMC in this study (mm)	Size range in till HMC in this study (mm)
W Minerals							
scheelite	$CaWO_4$	5.9-6.12	4-5	Nast & Williams-Jones (1991); Marr (2009)	0.1-0.5	0.025-2.0	0.025-2.0
wolframite	$(Fe,Mn)WO_4$	7.1-7.5	4.5	Nast & Williams-Jones (1991); Marr (2009)	0.04-0.08	0.025-2.0	0.025-1.0
Sulphides, Oxides							
molybdenite	MoS_2	5.5	1.0	Nast & Williams-Jones (1991); Marr (2009)	≤0.3	0.05-2.0	0.075-2.0
pyrite	FeS_2	5-5.02	6.5	Nast & Williams-Jones (1991); Marr (2009)	0.015-2.2	0.025-2.0	0.025-0.05
marcasite	FeS_2	4.89	6-6.5	no	not observed	0.025-0.10	not observed
chalcopyrite	$CuFeS_2$	4.1-4.3	3.5	Nast & Williams-Jones (1991); Marr (2009)	0.04-2.2	0.1-2.0	0.2-2.0
sphalerite	(Zn,Fe)S	3.9-4.2	3.5-4	Nast & Williams-Jones (1991); Marr (2009)	≤2.2	0.05-1.0	0.05-2.0
galena	PbS	7.2-7.6	2.5	Nast & Williams-Jones (1991); Marr (2009)	not observed	0.05-0.075	0.05
pyrrhotite	$Fe_{(1-x)}S$ (x=0-0.17)	4.58-4.65	3.5-4	Nast & Williams-Jones (1991); Marr (2009)	0.05-2.2	0.025-0.25	not observed
arsenopyrite	FeAsS	6.1	5	Nast & Williams-Jones (1991); Marr (2009)	not observed	not observed	0.05-2.0
mottramite	$Pb(Cu,Zn)(VO_4)(OH)$	5.9-6	3.5	no	not observed	not observed	0.25-0.5
Bi Minerals							
bismuthinite	Bi_2S_3	6.8-7.2	2.0	no	not observed	not observed	0.25-1.0
bismutite	$Bi_2(CO_3)O_2$	7.0	4.0	no	not observed	not observed	0.025-2.0
native bismuth	Bi	9.7-9.8	2-2.5	Nast & Williams-Jones (1991); Marr (2009)	0.01	not observed	0.025-1.0
joseite	$Bi_4(S,Te)_3$	8.1	2.0	no	not observed	not observed	0.025-0.5
Ag Minerals							
hessite	Ag_2Te	7.2-7.9	1.5-2	Nast & Williams-Jones (1991)	not observed	not observed	not observed
acanthite	Ag_2S	7.2-7.4	2-2.5	Nast & Williams-Jones (1991)	not observed	not observed	not observed

McClenaghan et al. (2013c).

Bedrock striations were measured on two outcrops 2 km northeast of the deposit (Fig. 2, 3). These new measurements are significant as striated outcrop is rare to non-existent in the deposit area. Both sets are oriented at 147–149º (no sense) and likely represent southeast ice-flow during the Early Wisconsinan Caledonia Phase. Surficial geology of the deposit area is described in more detail in McClenaghan et al. (2013c).

METHODS

Till sampling

In the summer of 2011, 56 large (~15 kg) till samples (11-MPB-502 to -553) were collected up-ice, overlying, and up to 14 km down-ice (southeast) of the deposit (Figs. 2,3) by the GSC and NBDEM in the summer of 2011 using GSC till sampling protocols (McClenaghan et al., 2013a). Samples sites within the known >30 km southeast-trending dispersal train (Fig. 4) were chosen to be as close as possible to the original NBDEM sample sites (Seaman, 2002, 2003, 2007; Seaman and McCoy, 2008). Surface till sampled in this study was likely the Early Wisconsinan lodgement till deposited by southeast glacial flow during the Caledonia Phase.

All till sample location data are listed in Appendix A. Detailed field notes and photos taken at each sample site are reported in GSC Open File 7430 (McClenaghan et al., 2013c). Most sample sites in the deposit area were freshly dug trenches excavated for sump drainage pits for diamond drillholes. After sampling, all field sites were marked with a labeled wooden stake. At each site, three till samples were collected: (1) a 8 to15 kg sample for recovery of indicator minerals; (2) a 3 kg till sample for geochemical analysis of the till matrix, till textural determinations, and archiving; and (3) a 200 g sample in a small clear plastic lunch bag for testing in the field using a portable bench top Innov-x 5000 XRF to provide preliminary information on the content of W, Sn, Cu, Mo, Bi, and As in till and to help guide till sampling on a daily basis.

Eight till samples for heavy mineral analysis were collected from three Northcliff Resources diamond drillholes, which were collared in the central part of the deposit, and cored till at the till/bedrock interface. These samples were collected to determine if compositions for till closer to the bedrock surface reflected the underlying subcropping bedrock. Drillholes sampled (Fig. 3) include

- DDH SB-11-016, till samples 11-MPB-532, -533, -534, and -579
- DDH SB-11-018, till sample 11-MPB-535
- DDH SB-11-007, till sample 11-MPB-536

Drillhole sample depths reported in Appendix A have been corrected to reflect true depth from the natural land surface as these samples were collected from inclined drillholes.

In 2012, one additional till sample (12-MPB-1026) was collected from the Zone 1 Discovery trench (Fig. 3) because this zone contains visible wolframite. It was

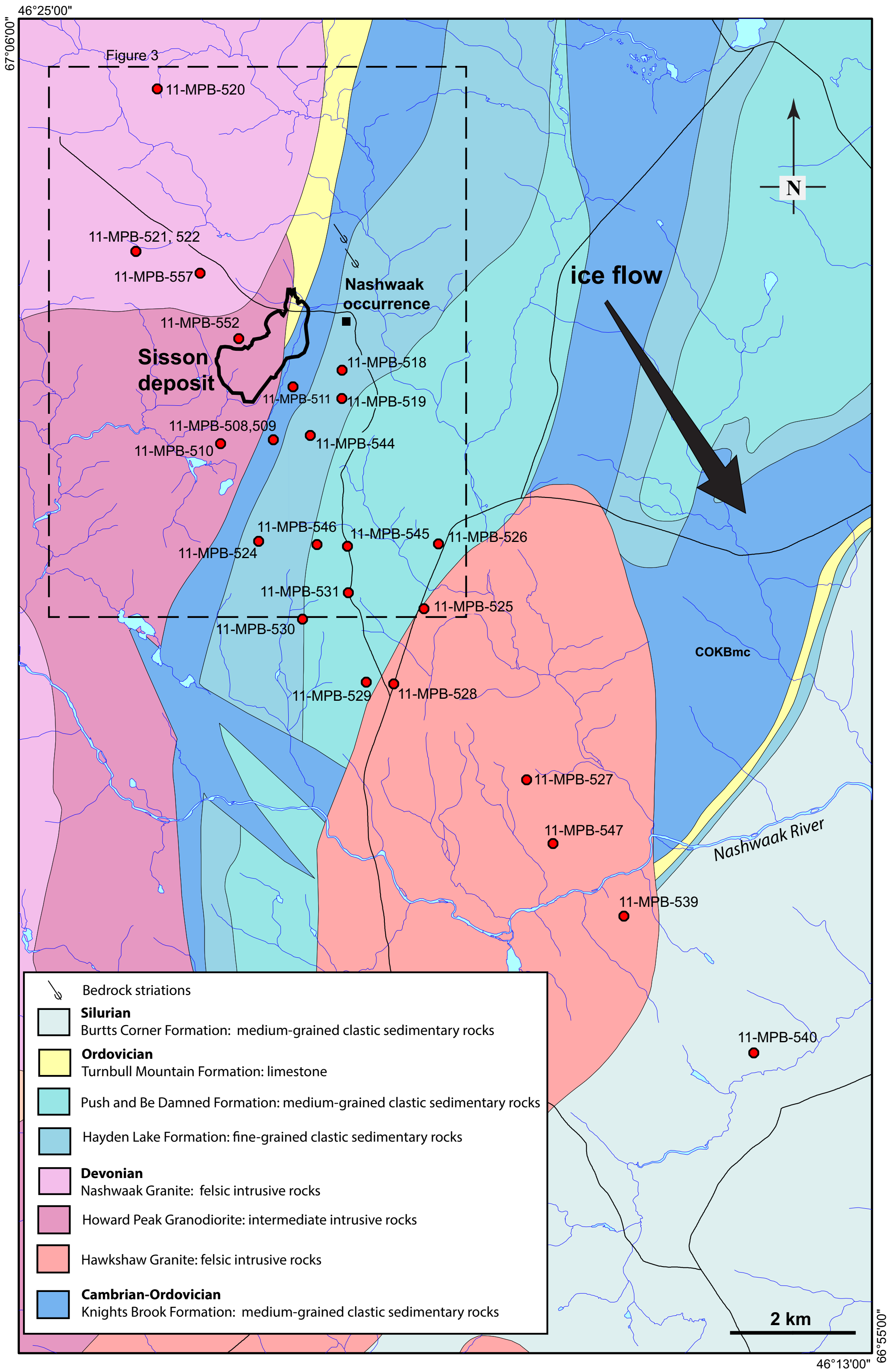


Figure 2. Local bedrock geology of the Sisson W-Mo deposit area and location of till samples (red dots) collected in 2007 up-ice (northwest), overlying, and down-ice (southeast) of the deposit. Bedrock geology modified from Smith and Fyffe (2006a-d). Deposit subcrop outline in black from Rennie (2012).

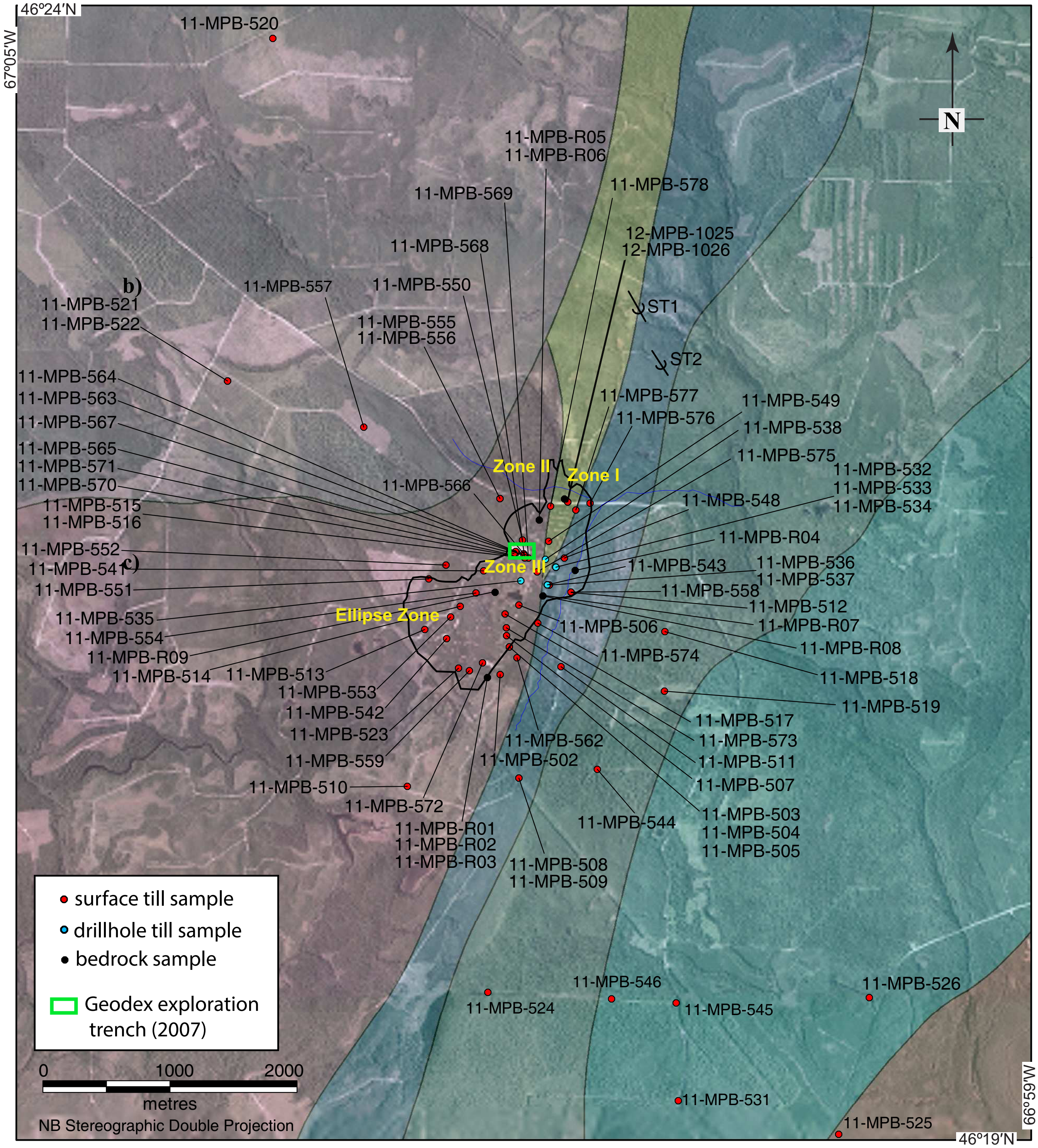


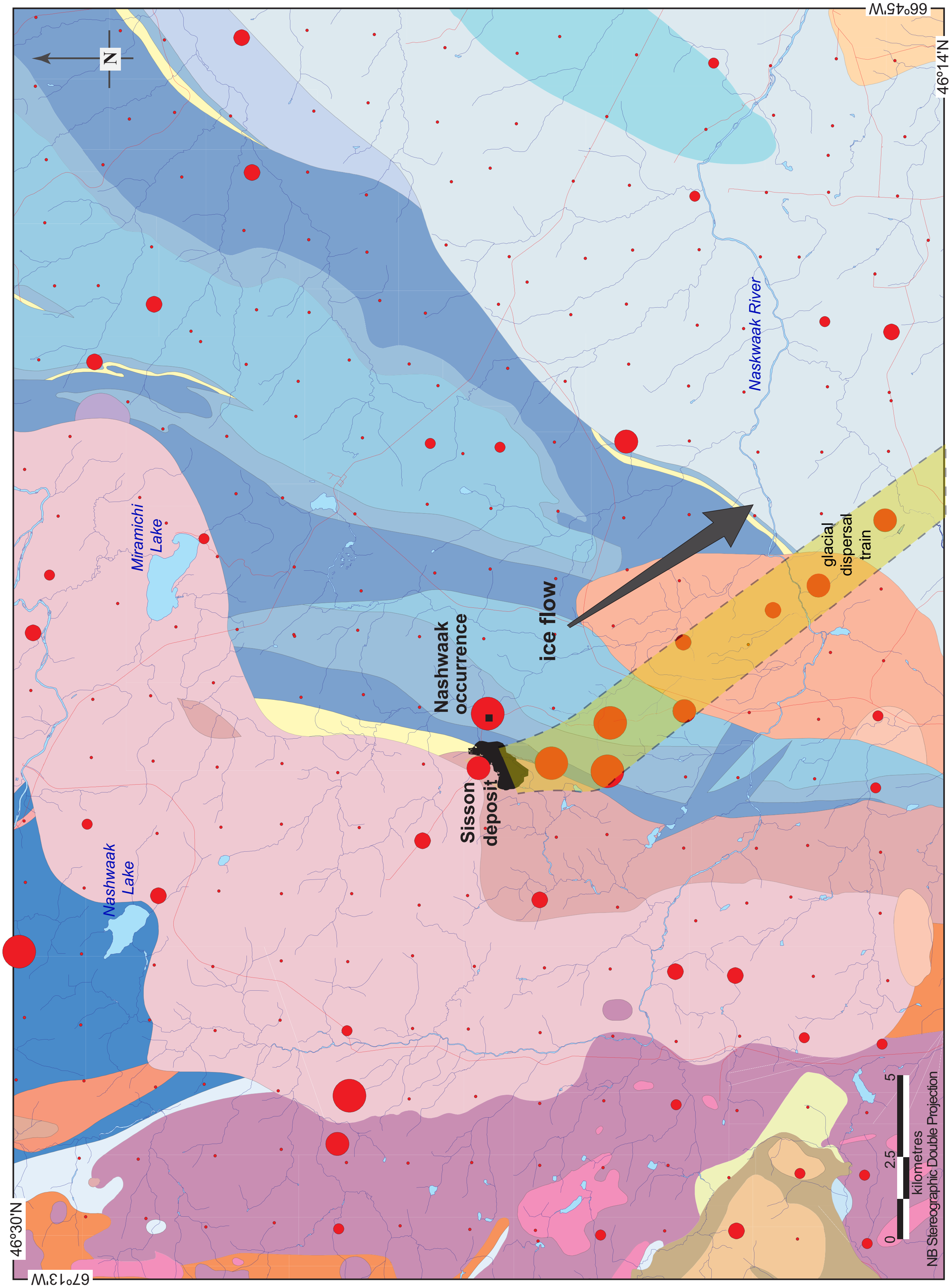
Figure 3. Location of till samples overlying and close to the Sisson W-Mo deposit. Deposit subcrop outline in black from Rennie (2012). Bedrock units are the same as those shown in Figure 2.

hoped that this till sample would contain wolframite grains that could be recovered and examined as part of the indicator mineral study of the deposit.

Three till sites were sampled as field duplicates in 2011 to assess field variability: sample 11-MPB-504 is a duplicate of -503, 11-MPB-522 is a duplicate of -521, and 11-MPB-556 is a duplicate of -555 (Fig. 3). Duplicates were collected from the same hole or trench as the original sample.

SAMPLE PROCESSING

Till samples were shipped to Overburden Drilling Management Limited (ODM), Ottawa for processing and production of heavy mineral concentrates. Sample


N
66°45'W
46°14'N
Naskwaak River
glacial
dispersal
train
ice flow
Nashwaak
occurrence
Sisson
deposit
Miramichi
Lake
Nashwaak
Lake
0
2.5
5
kilometres
NB Stereographic Double Projection
46°30'N
67°13'W

Carboniferous
- Mountain View Formation: medium-grained clastic sedimentary rocks
- Hardwood Ridge Basalt: mafic volcanic rocks
- Carlisle Formation: coarse-grained clastic sedimentary rocks
- Shin Formation: coarse-grained clastic sedimentary rocks

Devonian
- Nashwaak Granite: felsic intrusive rocks
- Howard Peak Granodiorite: intermediate intrusive rocks
- Becaguimec Lake Gabbro: felsic intrusive rocks
- Becaguimec Lake Gabbro: mafic intrusive rocks
- mafic intrusive rocks
- Allandale Granite: felsic intrusive rocks
- Hawkshaw Granite: felsic intrusive rocks
- Wapske Formation: medium-grained clastic sedimentary rocks
- Costigan Mountain Formation: felsic volcanic rocks

Silurian
- Taxis River Formation: medium-grained clastic sedimentary rocks
- Burtts Corner Formation: medium-grained clastic sedimentary rocks
- Cross Creek Formation: medium-grained clastic sedimentary rocks
- Bogan Brook Granodiorite: intermediate intrusive rocks
- Smyrna Mills Formation: fine-grained clastic sedimentary rocks

Ordovician
- Push and Be Damned Formation: medium-grained clastic sedimentary rocks
- Hayden Lake Formation: fine-grained clastic sedimentary rocks
- Turnbull Mountain Formation: limestone
- McKiel Lake Granite: felsic intrusive rocks
- Little Clearwater Brook Granite: felsic intrusive rocks

Cambrian-Ordovician
- Knights Brook Formation: medium-grained clastic sedimentary rocks
- Trousers Lake Metamorphic Suite: metamorphic rocks

W ppm
<0.063 mm (INAA)

Range	Percentile
14.3-81	>98 (6)
8.1-14.2	95-98 (6)
5.1-8.0	90-95 (14)
0.6-5.0	75-90 (19)
0.5	<75 (226)

Figure 4. Distribution of tungsten determined by instrumental neutron activation analysis in the <0.063 mm fraction of regional till samples collected by the New Brunswick Department of Natural Resources (now Department of Energy and Mines) in NTS map sheets 21J/02, 21J/03, 21J/06, and 21J/07, covering the area around the Sisson W-Mo deposit (data from Seaman, 2002, 2003, 2007; Seaman and McCoy, 2008). A glacial dispersal train from the Sisson W-Mo deposit (highighted in yellow) trends southeast from the deposit for at least 30 km and was used to guide till sampling for heavy mineral analysis in this study.

processing procedures are described in detail in GSC Open File 7387 (McClenaghan et al., 2013a). In 2011, 59 samples (56 till samples plus three quality control samples) were processed at ODM. One till sample was collected and processed in 2012 as part of a batch of till samples from the Mount Pleasant Sn-W-Mo-Bi-In deposit area. Similar to the bedrock samples, the <2.0 mm fraction of till was processed to produce a non-ferromagnetic heavy mineral concentrate for selection of indicator minerals (as outlined in McClenaghan et al., 2013a). Four 'blank' sand samples were inserted into the 2011 till batch prior to processing to monitor the quality of processing and picking at ODM: samples 11-MPB-501, -560, -561, and -580. The blank samples are weathered Silurian-Devonian granite (grus) of the South Nepisiguit River Plutonic Suite (Wilson, 2007) collected approximately 66 km west of Bathurst, New Brunswick (McClenaghan et al., 2012; Plouffe et al., in press). The material is thus informally referred to as the "Bathurst blank". Indicator mineral results for the four Bathurst blank samples are reported along with the till samples in McClenaghan et al. (2013a).

The 0.25–0.5, 0.5–1.0, and 1.0–2.0 mm non-ferromagnetic fractions of the till samples were examined by ODM. Potential indicator minerals of W-Mo mineralization were counted/selected, including scheelite, wolframite, and sulphide minerals as well as minerals listed in Table 3 of Averill (2001). All heavy mineral concentrates were systematically examined at ODM inside a black box using shortwave ultraviolet light (Fig. 5a). Scheelite was identified by its bright bluish white fluorescence under shortwave ultraviolet light (Fig. 5b–d).

In addition, the samples were scanned for potential indicators of massive sulphide deposits, including ODM's magmatic or metamorphosed massive sulphide indicator mineral (MMSIM®) suite. This suite is an indicator mineral assemblage used to explore for a broad spectrum of sulphide-associated deposits (Table 2 in Averill, 2001). The samples were also examined for indicators of other deposit types, including gold.

Data plotting

For field duplicates, the data for the first sample of each duplicate pair was used in calculation of statistics and for plotting distribution maps. Only surface till samples were used to plot indicator mineral maps, thus samples 11-MPB-532 to -538 collected from diamond drillholes were not included. Proportional dot maps showing the abundance of selected elements were plotted using MapInfo Professional® Version 7.8.

RESULTS

Quality assurance/quality control

Blank samples

Indicator mineral counts for the 0.25–0.5 mm fraction

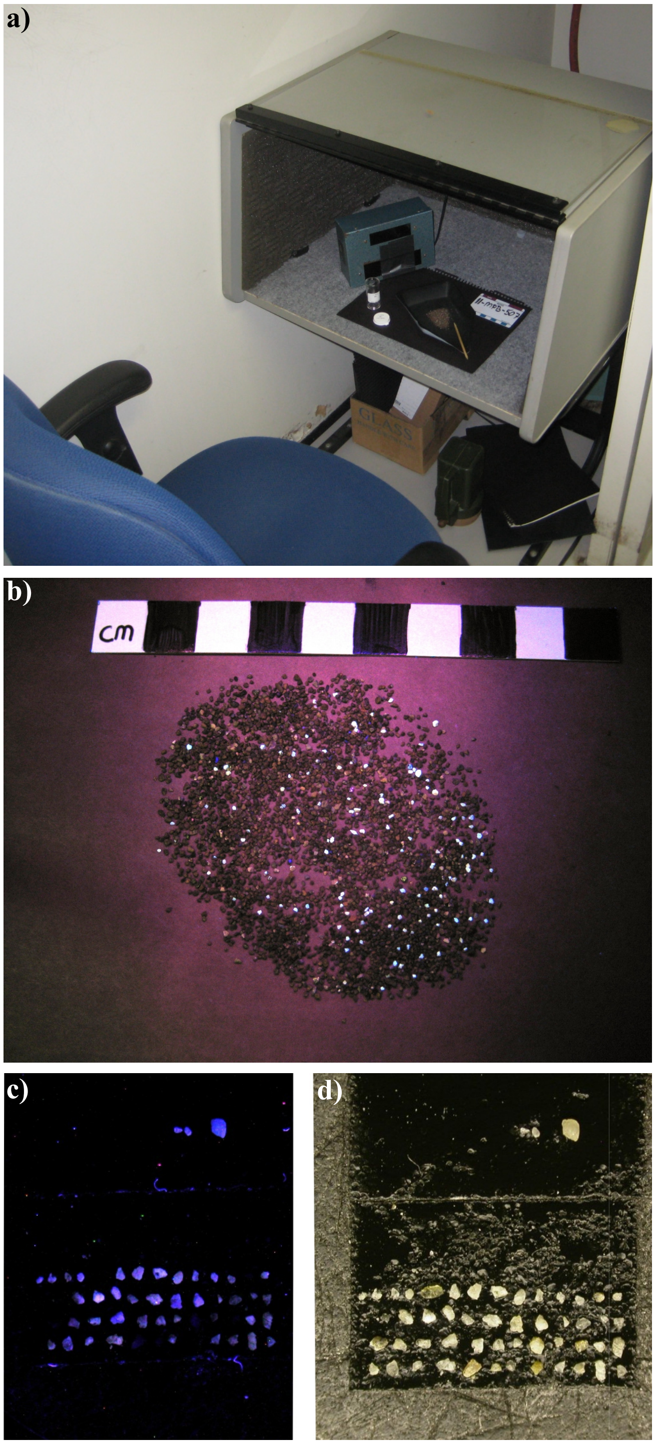


Figure 5. a) Black box and ultraviolet light lamping station used at Overburden Drilling Management Ltd. to examine all till samples for scheelite; **b)** 0.5–1.0 mm heavy mineral fraction of till sample 11-MPB-506 with abundant scheelite grains fluorescing bluish white under UV light; **c)** scheelite grains from till sample 11-MPB-504 mounted on SEM stub under UV light; and **d)** scheelite grains from till sample 11-MPB-504 mounted on SEM stub under normal light.

of the four Bathurst blank samples, included in the 2011 till sample batch, are reported in Table 2. In the 0.25–0.5 mm fraction, sample 11-MPB-501 contained 10 goethite grains and sample 11-MPB-580 contained 100 goethite grains. The other two Bathurst blanks contained no goethite. Previous data reported for the Bathurst blank indicate that it does not contain goethite (Oviatt et al., 2013; Plouffe et al., in press). Thus, the goethite in sample 11-MPB-501, which was processed at the beginning of the sample batch, is likely contamination from a previous batch and the goethite in sample 11-MPB-580 is likely from the 3 or 4 goethite-rich till samples (1000–5000 grains) that were processed before it.

The pan concentrate of sample 11-MPB-580 contained one gold grain, and the other three blank samples contained none. This one grain is likely an occasional background gold grain, which the blank material has been reported to contain (Plouffe et al., in press).

Till field duplicates

Indicator mineral counts for the three field duplicate pairs are reported in Table 2.

Although till samples 11-MPB-503 and -504 were collected at slightly different depths in the same trench, both contain similar contents of goethite (1000s of grains) and between 1 and 3 grains of chalcopyrite. However, sample 11-MPB-503 contains more than twice as much scheelite as -504. Sample 11-MPB-503 contains a few grains of pyrite and one grain of molybdenite. Differences between these two samples may be related to sample depth as well as natural variability between samples.

Field duplicate sample pairs 11-MPB-521 and -522, and 11-MPB-555 and -556 have much lower indicator mineral counts and more indicator mineral grain abundances that are similar between the pairs than the other field duplicate pair (samples 11-MPB-503 and -504) (Table 2). Results for these two pairs indicate that, in background areas or areas far down-ice, scheelite counts may vary by +/- 2 grains.

Scheelite

Scheelite ($CaWO_4$) was identified in till heavy mineral concentrates (HMC) by its pale yellow colour, cleavage, and bright white fluorescence under shortwave UV light (McClenaghan et al., 2013b). It is present in pan concentrates and in the three size fractions up to 2.0 mm in HMC (Table 3). In samples that contain >25 grains of scheelite in the 0.25–0.5 mm fraction, scheelite was also recovered from the pan concentrate, with some grains as small as 25 µm. Of the three coarsest size fractions, scheelite is most abundant in the 0.25–0.5 mm fraction. Its abundance varies from background values of zero to 2 grains in till up-ice (northwest) of the deposit (background) and to 4700 grains in till overlying the deposit (Table 3; Appendix B map 1). Coarser scheelite is present in the 0.5–1.0 and 1.0–2.0

Table 2. Indicator minerals recovered from (a) four Bathurst blanks inserted in the till batch prior to sample processing; and (b) three till field duplicates overlying mineralization and up-ice (background), with counts normalized to 10 kg weight of <2 mm table feed (summarized from McClenaghan et al., 2013a).

Sample Number	Location	Sample Depth	Weight (kg)	Chalcopyrite	Scheelite	Molybdenite	Bismutite	Pyrite	Goethite	Spinel	Misc. Prime MMSIMs	Red Rutile	Kyanite	Sillimanite	Tourmaline	Staurolite	Spessartine	Olivine	Orthopx	Chromite	Apatite	Monazite
Bathurst Blanks																						
11-MPB-501	na	na	9.3	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
11-MPB-580	na	na	9.6	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
11-MPB-560	na	na	9.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11-MPB-561	na	na	8.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Field Duplicates																						
11-MPB-503 (duplicate 1)	over mineralization	2.0-2.3	8.9	1	1685	0	0	0	8989	0	0	1	0	11	2	11	6	0	0	0	899	0
11-MPB-504 (duplicate 2)	over mineralization	2.5-2.8	9.7	3	619	1	0	5	5155	0	0	2	21	52	2	0	0	0	0	0	825	1
11-MPB-521 (duplicate 1)	up-ice	1.2-1.4	12.8	0	2	0	0	0	781	0	0	0	0	3	0	4	0	0	31	1	625	0
11-MPB-522 (duplicate 2)	up-ice	1.2-1.4	12.7	0	0	0	0	0	394	0	0	0	0	12	0	0	0	0	0	0	157	0
11-MPB-555 (duplicate 1)	up-ice	0.8-1.1	12.1	0	1	0	0	0	83	0	0	1	8	83	4	0	17	0	0	0	1653	0
11-MPB-556 (duplicate 2)	up-ice	0.8-1.1	12.3	0	1	0	1	0	1626	0	Mn-epidote (1 gr); ruby corundum (1 g)	5	0	81	8	0	4	0	122	0	976	4

mm fractions of till up to 2 km down-ice (Appendix B maps 2,3).

Wolframite

Wolframite ($(Fe,Mn)WO_4$) was identified in till HMC by its black colour, prismatic crystal form, softness (H=4.5, can be scratched with a needle), and reddish brown streak (McClenaghan et al., 2013b). It was recovered from both the 0.25–0.5 mm (Table 3) and 0.5–1.0 mm fractions of only one till sample (12-MPB-1026), which was collected over the Discovery trench at Zone I, at the north end of the deposit (Appendix B, map 4). The background content of wolframite in till is zero grains away from the deposit.

Molybdenite

The background content of molybdenite in till is zero grains away from the deposit. Between 1 and 8 grains of molybdenite were recovered from the 0.25–0.5 mm fraction of several till samples collected over the deposit (Table 3; Appendix B, map 5). Sample 11-MPB-567 contains the most molybdenite, 87 grains in the 0.25–0.5 mm fraction. Molybdenite was also recovered from the coarse fraction of four till samples collected overlying the deposit: samples 11-MPB-532 from 11 m depth, 11-MPB-567 from 1.5 m depth, 11-MPB-568 from 4.0 m depth, and 11-MPB-579 from 20 m depth. The pan concentrate of three of these samples (11-MPB-532, -576, and -579) also contained molybdenite (Table 3).

Chalcopyrite

Background content of chalcopyrite in till is zero grains away from the deposit. Chalcopyrite was recovered from the 0.25–0.5 mm fraction of till samples collected over the deposit as well as from four samples up to 2.5 km down-ice (samples 11-MPB-574, 11-MPB-511, 11-MPB-546, and 11-MPB-544 (Table 3; Appendix B, map 6). The 0.25–0.5 mm fraction of sample 11-MPB-579 contained the most chalcopyrite (78 grains). Chalcopyrite was recovered from the coarse fraction of 14 samples, all of which were collected overlying the deposit.

Pyrite

Pyrite and marcasite grains were recovered from pan concentrates of several till samples, most notably from unoxidized till from overburden drill core samples 11-MPB-532 to -536 as well as from surface sample 11-MPB-576 (Table 3). Background values are zero grains in till up-ice. In the 0.25–0.5 mm fraction of till, pyrite and marcasite are most abundant in the same six drill core samples as well as in surface samples 11-MPB-502 collected 50 m down-ice, and 11-MPB-510 collected 900 m down-ice of the deposit. No coarse (>0.5

Table 3. Abundance of ore minerals in the pan concentrate (not normalized) and the 0.25–0.5 mm, 0.5–1.0 mm, and 1.0–2.0 mm non-ferromagnetic fractions of all till samples (normalized to 10 kg of <2 mm table feed) collected at surface and from drill core, listed in increasing distance down-ice from the Sisson deposit.

Sample Number	Type of Till Sample	Interpretation	Distance from Deposit (m)	Pan Concentrate						0.25-0.5 mm									
				Sch	Wf	Mo	Cpy	Apy	Py/ Mrc	Sch	Wf	Mo	Cpy	Apy	Py	Bi minerals	Gn	Sph	Diamond (contam)
11-MPB-520	surface	background up-ice	-4000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11-MPB-521	surface	background up-ice	-2250	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
11-MPB-552	surface	proximal up-ce	-200	0	0	0	0	0	0	7	0	0	1	0	0	6	0	0	0
11-MPB-555	surface	proximal up-ice	-200	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
11-MPB-503	surface	overlying mineralization	0	200	0	0	0	0	0	1685	0	0	1	0	0	0	0	0	0
11-MPB-504	surface	overlying mineralization	0	50,000	0	0	0	0	0	619	0	1	3	0	5	0	0	0	0
11-MPB-505	surface	overlying mineralization	0	0	0	0	0	0	0	515	0	0	1	0	0	0	0	0	0
11-MPB-507	surface	overlying mineralization	0	150,000	0	0	0	0	0	4706	0	0	0	0	0	0	1	0	0
11-MPB-513	surface	overlying mineralization	0	0	0	0	0	0	0	83	0	0	2	0	0	14	0	0	0
11-MPB-514	surface	overlying mineralization	0	0	0	0	0	0	0	8	0	0	2	0	0	0	0	0	0
11-MPB-517	surface	overlying mineralization	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0
11-MPB-523	surface	overlying mineralization	0	15	0	0	0	0	0	47	0	0	10	0	118	0	0	0	0
11-MPB-532	drill core	overlying mineralization	0	0	0	1	0	1,000	3,000	0	0	8	11	21	1212	0	0	1	5
11-MPB-533	drill core	overlying mineralization	0	1	0	0	0	50	5,000	21	0	1	19	16	2609	0	0	4	14
11-MPB-534	drill core	overlying mineralization	0	0	0	0	0	25	3,000	3	0	1	32	48	2381	0	0	0	2
11-MPB-535	drill core	overlying mineralization	0	40	0	0	0	10	5,000	82	0	4	17	16	2041	1	0	2	17
11-MPB-536	drill core	overlying mineralization	0	0	0	0	0	5	3,000	1	0	1	22	6	1163	0	1	1	19
11-MPB-543	surface	overlying mineralization	0	0	0	0	0	0	0	283	0	0	3	0	47	1	0	0	0
11-MPB-548	surface	overlying mineralization	0	0	0	0	0	0	10	57	0	0	1	0	0	0	0	0	0
11-MPB-551	surface	overlying mineralization	0	200	0	0	0	0	50	303	0	0	12	0	202	0	0	0	0
11-MPB-553	surface	overlying mineralization	0	0	0	0	0	0	20	122	0	0	17	0	203	0	0	0	0
11-MPB-558	surface	overlying mineralization	0	1	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0
11-MPB-566	surface	overlying mineralization	0	0	0	0	0	0	0	5	0	0	1	0	4	0	0	0	0
11-MPB-567	surface	overlying mineralization	0	50	0	0	0	0	0	261	0	87	8	0	217	2	0	0	0
11-MPB-568	surface	overlying mineralization	0	50	0	0	0	0	0	450	0	4	7	1	18	1	0	1	0
11-MPB-569	surface	overlying mineralization	0	100	0	0	0	0	20	435	0	0	0	0	9	0	0	0	0
11-MPB-572	surface	overlying mineralization	0	200	0	0	0	0	0	208	0	0	4	0	4	2	0	0	0
11-MPB-573	surface	overlying mineralization	0	5,000	0	0	0	0	0	1852	0	4	0	0	2	1	0	0	0
11-MPB-575	surface	overlying mineralization	0	50	0	0	0	0	0	189	0	0	0	0	5	0	0	0	0
11-MPB-576	surface	overlying mineralization	0	0	0	3	0	100	5,000	2	0	0	6	1	1154	0	0	0	0
11-MPB-577	surface	overlying mineralization	0	1,000	0	0	0	20	100	1266	0	0	16	0	25	0	0	0	0
11-MPB-578	surface	overlying mineralization	0	50	0	0	0	0	0	13	0	0	0	0	2	0	0	0	0
11-MPB-579	drill core	overlying mineralization	0	100	0	10	3	250	200	78	0	59	78	29	2451	0	0	1	0
12-MPB-1026	surface	overlying mineralization	0	200	0	0	0	0	0	280	112	0	0	1	0	0	0	0	0
11-MPB-574	surface	proximal down-ice	20	50	0	0	0	0	20	5	0	0	1	7	29	0	0	0	0
11-MPB-502	surface	proximal down-ice	50	0	0	0	0	0	0	40	0	0	6	0	1200	2	0	0	0
11-MPB-562	surface	proximal down-ice	100	200	0	0	0	0	0	404	0	0	1	0	10	1	0	0	0
11-MPB-511	surface	proximal down-ice	275	0	0	0	0	0	0	36	0	0	2	0	0	0	0	0	0
11-MPB-518	surface	proximal down-ice	650	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11-MPB-508	surface	proximal down-ice	750	200	0	0	0	0	0	76	0	1	0	0	0	0	0	0	0
11-MPB-509	surface	proximal down-ice	750	200	0	0	0	0	0	38	0	0	0	0	0	1	0	0	0
11-MPB-510	surface	proximal down-ice	900	0	0	0	0	0	0	0	0	0	0	0	708	0	0	0	0
11-MPB-544	surface	proximal down-ice	1000	0	0	0	0	0	0	49	0	0	1	0	0	0	0	0	0
11-MPB-519	surface	distal down-ice	1100	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0
11-MPB-524	surface	distal down-ice	2250	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0
11-MPB-546	surface	distal down-ice	2500	0	0	0	0	0	0	2	0	0	2	0	0	1	0	0	0
11-MPB-545	surface	distal down-ice	2800	0	0	0	0	0	0	19	0	0	0	0	0	7	0	0	0
11-MPB-531	surface	distal down-ice	3500	0	0	0	0	0	0	3	0	0	0	0	0	4	0	0	0
11-MPB-526	surface	distal down-ice	3600	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
11-MPB-530	surface	distal down-ice	3600	0	0	0	0	0	10	0	0	0	0	0	2	0	0	0	0
11-MPB-525	surface	distal down-ice	4300	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0
11-MPB-528	surface	distal down-ice	5000	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
11-MPB-529	surface	distal down-ice	5000	0	0	0	0	0	20	0	0	0	0	0	18	0	0	0	0
11-MPB-527	surface	distal down-ice	8500	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
11-MPB-547	surface	distal down-ice	8750	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11-MPB-539	surface	distal down-ice	10000	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0
11-MPB-540	surface	distal down-ice	13000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NOTE: Apy = arsenopyrite; Cpy = chalcopyrite; Gn = galena; Mo = molybdenite; Py = pyrite; Sch = scheelite; Sph = sphalerite; Wf = wolframite

Table 2 continued.

Sample Number	Type of Till Sample	Interpretation	Distance from Deposit (m)	0.5-1.0 mm						1.0-2.0 mm					
				Sch	Wf	Mo	Cpy	Apy	Bi minerals	Sch	Wf	Mo	Cpy	Apy	Bi minerals
11-MPB-520	surface	background up-ice	-4000	0	0	0	0	0	0	0	0	0	0	0	0
11-MPB-521	surface	background up-ice	-2250	0	0	0	0	0	0	0	0	0	0	0	0
11-MPB-552	surface	proximal up-ce	-200	3	0	0	0	0	2	0	0	0	0	0	0
11-MPB-555	surface	proximal up-ice	-200	0	0	0	0	0	0	0	0	0	0	0	0
11-MPB-503	surface	overlying mineralization	0	67	0	0	0	0	0	4	0	0	0	0	0
11-MPB-504	surface	overlying mineralization	0	82	0	0	0	0	0	7	0	0	0	0	0
11-MPB-505	surface	overlying mineralization	0	62	0	0	0	0	0	3	0	0	0	0	0
11-MPB-507	surface	overlying mineralization	0	141	0	0	0	0	1	9	0	0	0	0	0
11-MPB-513	surface	overlying mineralization	0	12	0	0	1	0	5	0	0	0	0	0	2
11-MPB-514	surface	overlying mineralization	0	0	0	0	0	0	0	0	0	0	0	0	0
11-MPB-517	surface	overlying mineralization	0	1	0	0	0	0	0	0	0	0	0	0	0
11-MPB-523	surface	overlying mineralization	0	6	0	0	1	0	0	0	0	0	0	0	0
11-MPB-532	drill core	overlying mineralization	0	0	0	2	0	2	0	0	0	0	1	2	0
11-MPB-533	drill core	overlying mineralization	0	3	0	0	1	5	0	0	0	0	0	0	0
11-MPB-534	drill core	overlying mineralization	0	1	0	0	2	5	1	0	0	0	0	0	0
11-MPB-535	drill core	overlying mineralization	0	8	0	0	1	3	0	0	0	0	0	0	0
11-MPB-536	drill core	overlying mineralization	0	0	0	0	1	0	0	0	0	0	0	0	0
11-MPB-543	surface	overlying mineralization	0	47	0	0	0	0	0	2	0	0	0	0	0
11-MPB-548	surface	overlying mineralization	0	17	0	0	0	0	0	2	0	0	0	0	0
11-MPB-551	surface	overlying mineralization	0	33	0	0	0	0	1	1	0	0	0	0	0
11-MPB-553	surface	overlying mineralization	0	6	0	0	3	0	0	1	0	0	0	0	0
11-MPB-558	surface	overlying mineralization	0	4	0	0	0	0	0	0	0	0	0	0	0
11-MPB-566	surface	overlying mineralization	0	0	0	0	0	0	0	0	0	0	0	0	0
11-MPB-567	surface	overlying mineralization	0	40	0	42	2	0	0	4	0	7	0	0	0
11-MPB-568	surface	overlying mineralization	0	90	0	2	2	0	0	4	0	0	0	0	0
11-MPB-569	surface	overlying mineralization	0	43	0	0	0	0	0	3	0	0	0	0	0
11-MPB-572	surface	overlying mineralization	0	33	0	0	0	0	0	7	0	0	0	0	0
11-MPB-573	surface	overlying mineralization	0	74	0	0	0	0	0	4	0	0	0	0	0
11-MPB-575	surface	overlying mineralization	0	8	0	0	0	0	0	0	0	0	0	0	0
11-MPB-576	surface	overlying mineralization	0	1	0	0	1	0	0	0	0	0	0	0	0
11-MPB-577	surface	overlying mineralization	0	0	0	0	1	0	0	0	0	0	0	0	0
11-MPB-578	surface	overlying mineralization	0	2	0	0	0	0	0	0	0	0	0	0	0
11-MPB-579	drill core	overlying mineralization	0	4	0	15	1	0	6	0	0	0	0	0	0
12-MPB-1026	surface	overlying mineralization	0	16	36	0	0	1	0	1	0	0	0	0	0
11-MPB-574	surface	proximal down-ice	20	4	0	0	0	0	0	0	0	0	0	0	0
11-MPB-502	surface	proximal down-ice	50	2	0	0	0	0	0	0	0	0	0	0	0
11-MPB-562	surface	proximal down-ice	100	40	0	0	0	0	0	4	0	0	0	0	0
11-MPB-511	surface	proximal down-ice	275	0	0	0	0	0	0	0	0	0	0	0	0
11-MPB-518	surface	proximal down-ice	650	0	0	0	0	0	0	0	0	0	0	0	0
11-MPB-508	surface	proximal down-ice	750	3	0	0	0	0	0	1	0	0	0	0	0
11-MPB-509	surface	proximal down-ice	750	6	0	0	0	0	0	0	0	0	0	0	0
11-MPB-510	surface	proximal down-ice	900	0	0	0	0	0	0	0	0	0	0	0	0
11-MPB-544	surface	proximal down-ice	1000	7	0	0	0	0	0	1	0	0	0	0	0
11-MPB-519	surface	distal down-ice	1100	1	0	0	0	0	0	0	0	0	0	0	0
11-MPB-524	surface	distal down-ice	2250	0	0	0	0	0	0	0	0	0	0	0	0
11-MPB-546	surface	distal down-ice	2500	0	0	0	1	0	0	0	0	0	0	0	0
11-MPB-545	surface	distal down-ice	2800	0	0	0	0	0	0	0	0	0	0	0	0
11-MPB-531	surface	distal down-ice	3500	0	0	0	0	0	0	0	0	0	0	0	0
11-MPB-526	surface	distal down-ice	3600	0	0	0	0	0	0	0	0	0	0	0	0
11-MPB-530	surface	distal down-ice	3600	0	0	0	0	0	0	0	0	0	0	0	0
11-MPB-525	surface	distal down-ice	4300	0	0	0	0	0	0	0	0	0	0	0	0
11-MPB-528	surface	distal down-ice	5000	0	0	0	0	0	0	0	0	0	0	0	0
11-MPB-529	surface	distal down-ice	5000	0	0	0	0	0	0	0	0	0	0	0	0
11-MPB-527	surface	distal down-ice	8500	0	0	0	0	0	0	0	0	0	0	0	0
11-MPB-547	surface	distal down-ice	8750	0	0	0	0	0	0	0	0	0	0	0	0
11-MPB-539	surface	distal down-ice	10000	0	0	0	0	0	0	0	0	0	0	0	0
11-MPB-540	surface	distal down-ice	13000	0	0	0	0	0	0	0	0	0	0	0	0

NOTE: Apy = arsenopyrite; Cpy = chalcopyrite; Gn = galena; Mo = molybdenite; Py = pyrite; Sch = scheelite; Sph = sphalerite; Wf = wolframite mm) pyrite or marcasite was seen in any of the samples.

Arsenopyrite

Between 5 and 1000 arsenopyrite grains, ranging in size from 50 to 7500 µm, were recovered from the pan concentrates of unoxidized till from drill core samples 11-MPB-532 to -536 and 11-MPB-579 as well as from surface samples 11-MPB-576, 11-MPB-577, and 12-MPB-1026 (Table 3). In the 0.25–0.5 mm fraction, up to 48 arsenopyrite grains were recovered from drill core samples, as well as from samples 11-MPB-568, 11-MPB-574, 11-MPB-576, and 12-MPB-1026 (Appendix B, map 7). A few very large arsenopyrite grains were recovered in the 0.5–1.0 and 1.0–2.0 mm fractions of drill core sample 11-MPB-532, and in the 0.5–1.0 mm fractions of drill core samples 11-MPB-533 to -535 and sample 12-MPB-1026.

Bi-bearing minerals

Bi-bearing minerals recovered from till include joseite ($Bi_4(S,Te)_3$), native Bi, bismuthinite (Bi_2S_3), and bismutite ($Bi_2(CO_3)O_2$) (Table 1). They were recovered from a broad range of size fractions, from pan concentrates up to the 1.0–2.0 mm fraction of till (Table 3). These minerals occur in till overlying the deposit as well as up to 3 km down-ice. The total number of all Bi-bearing minerals in the 0.25–0.5 mm fraction was plotted for each till sample in map 8 of Appendix B.

Sphalerite

A few grains of sphalerite were recovered from the 0.25–0.5 mm fractions of drill core till samples as well as sample 11-MPB-568, all of which overlie the deposit (Table 3; Appendix B, map 9).

Galena

A few galena grains, between 50 and 500 µm in size, were recovered from the pan concentrates of till samples 11-MPB-503, 11-MPB-532, 11-MPB-534, 11-MPB-536, and 11-MPB-576. Sixty grains were recovered from sample 11-MPB-579. Two coarser galena grains (0.25–0.5 mm) were also recovered from till samples 11-MPB-536 and 11-MPB-507. All galena grains were recovered from till samples overlying the deposit.

Contamination

Between 2 and 19 grains of industrial (yellow-brown colour) diamonds (Fig. 6) were recovered from the 0.25–0.5 mm HMC of till samples 11-MPB-532 to -536, which were collected from diamond drill core (Table 3). The diamonds are contamination from the diamond drill bits used to core the till from which these samples were collected.

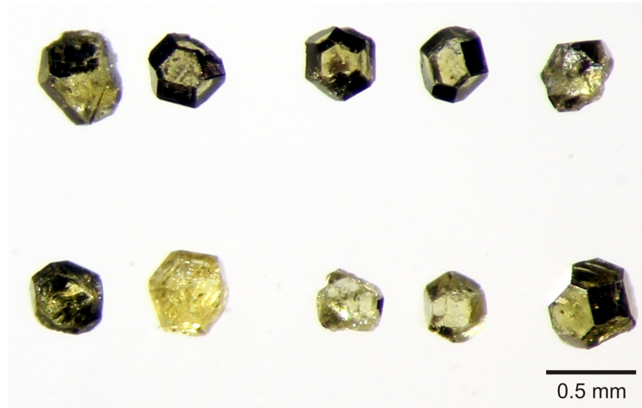


Figure 6. Industrial diamonds (contamination) recovered from the 0.25–0.5 mm fraction of till sample 11-MPB-535. This till sample was collected from diamond drill core.

DISCUSSION

Indicator minerals of W-Mo mineralization

The primary Sisson ore minerals recovered from till samples include scheelite, wolframite, and molybdenite. These are heavy minerals (Table 1) that are visually distinct and easily recovered by the common surficial sample processing method that uses tabling and heavy liquids (McClenaghan, 2011) to recover indicator minerals. Secondary ore minerals that have been identified in till samples from around the Sisson deposit include chalcopyrite, Bi-rich minerals (joseite, native Bi, bismutite, bismuthinite), galena, sphalerite, arsenopyrite, pyrrhotite, and pyrite. These minerals do not occur in great abundant in the till but are still useful indicators of the polymetallic nature of the Sisson deposit. This suite of primary and secondary indicator minerals is the same suite of indicator minerals identified in mineralized bedrock samples from the Sisson deposit (McClenaghan et al., 2013b), with the exception of the Bi-minerals. Only native Bi was identified in bedrock samples (Table 1). In till overlying and up to 3 km down-ice, three additional Bi minerals were recovered from till: joseite, bismutite, and bismuthinite. All of the indicator minerals listed here will be useful for W-Mo exploration in the region using till and stream sediment sampling.

Arsenopyrite and pyrite are significantly more abundant in fresh till sampled in drill core than in slightly weathered till collected at surface. These abundance differences indicate that pyrite and arsenopyrite are less stable in surface till and will be significantly affected (destroyed) by postglacial weathering of till.

Scheelite

Scheelite is a well known indicator mineral of W, Sn, and Au mineralization. Scheelite is used as an indicator mineral in stream sediments because it survives longer in surficial weathering environments than sulphides, it's heavy specific gravity (SG 5.9–6.12) allows it to be easily recovered, and it is easily identified by its bright white fluorescence under shortwave UV light. It has been recovered from stream sediments in support of W, Sn, and Au exploration in many parts of the world (e.g. Zeschke, 1961), including Turkey (e.g. Özcan and Çağatay, 1989), Spain (e.g. Fernández-Turiel et al., 1992), and India (e.g. de Smeth et al., 1985), as well as the glaciated terrains of Norway (e.g. Stendal,1978), Greenland (e.g. Hallenstien et al., 1981), and Canada (e.g. Maurice, 1986). It is, however, much less widely known as an indicator mineral in glacial sediments.

The use of scheelite as an indicator mineral in till was first reported by Lindmark (1977) and Brundin and Bergström (1977) in the glaciated terrain of Fennoscandia. Lindmark (1977) describes one of the first till sampling programs specifically designed to recover scheelite in till. This till sampling, which was carried out in Finland in the 1960s, was conducted to investigate the source of W-rich boulders. The till sampling program, which was combined with boulder tracing, led to the discovery of scheelite-rich bedrock.

Brundin and Bergström (1977) tested indicator mineral methods in Sweden. First they compared the success of exploration programs using till sampling versus those using stream sediments. They also investigated variations of till sampling methods, i.e., varying sample weights (2.5 kg versus 25 kg), preconcentration methods (panning versus sluice box), and heavy liquid separation densities (SG 2.96 versus 3.3). They concluded that in large parts of Sweden, indicator mineral surveys using till are more effective than those using stream sediment. One of the key indicator minerals they reported finding was scheelite, which was recovered from the non-magnetic SG >3.3 fraction of till. Scheelite was rare to absent in background till samples; they therefore concluded that its presence in till HMC directly indicated the presence of bedrock mineralization.

In the 1970s and 1980s, several studies compared W contents in till matrix or HMC fractions to scheelite grain contents in till (e.g. Nikkarinen and Bjorklund, 1976; Steiger, 1977; Stea and O'Reilly, 1982; Toverud, 1984; Johansson et al., 1986; Petersen and Stendal, 1987; Salminen and Hartikainen, 1986; Snow and Coker, 1987; Coker et al., 1988, Peuraniemi, 1992). It was often noted that scheelite grains in till formed larger anomalies than those outlined using W content in till.

Fluorescence of scheelite

Scheelite fluoresces bright whitish blue under shortwave UV light. Mo-rich scheelite from Zone III of the Sisson deposit (Marr, 2009) fluoresces bright yellow under shortwave UV light. This fluorescence is important to the visual identification and systematic counting of scheelite grains in till HMC in this study. Other heavy minerals that can be common in till HMC fluoresce but their colours are distinct from that of scheelite. For example, under short- and long-wave UV light zircon will fluoresce yellow and orange-green, sphalerite will fluoresce yellow-orange, and fluorite will fluoresce blue.

Indicator mineral size

The size of indicator minerals in till is controlled primarily by the size of the grains in the source rock and the durability of the mineral during glacial transport. Table 1 lists the size of indicator minerals observed in mineralized bedrock and till samples in this study. Mineral durability is indicated by the mineral hardness. Scheelite grains up to 2 mm in size were found in bedrock and till samples down-ice, although most grains occurred in the pan concentrate (<0.25 mm) and the 0.25–0.5 mm fractions of till. Scheelite grains 0.5–1.0 mm and 1.0–2.0 mm in size were found in till up to 1.1 km down-ice. Thus the presence of coarse scheelite in till can be an indicator of proximity to bedrock source.

Similar to scheelite, wolframite, molybdenite, chalcopyrite, sphalerite, and bismutite are most abundant in the finer till fractions, but a few coarse (1.0–2.0 mm) grains were found proximal to the deposit.

Distance of glacial transport

Table 4 offers a guide to indicator mineral abundances that might be expected in surface till samples, at various glacial transport distances down-ice from a W-Mo mineralized source.

CONCLUSIONS AND IMPLICATIONS FOR EXPLORATION

This till indicator mineral study is the first case study around a major W-Mo deposit in glaciated terrain. It is also the first indicator mineral study conducted in any terrain to identify for this deposit type a broad suite of indicator minerals in addition to scheelite and molybdenite. Indicator minerals in 10 kg till samples clearly define glacial dispersal at least 10 km down-ice (southeast) of the Sisson W-Mo deposit in widely (5 km) spaced samples. Therefore, heavy mineral sampling is recommended for regional exploration programs searching for W-Mo deposits in similar geological terranes.

Indicator minerals for this type of W-Mo deposit include the primary ore minerals, scheelite, wolframite, and molybdenite, as well as secondary ore minerals, chalcopyrite, joseite, native Bi, bismutite, bismuthinite, galena, sphalerite, arsenopyrite, pyrrhotite, and pyrite.

Table 4. Abundance of ore minerals in the 0.25–0.5 mm non-ferromagnetic fraction of selected till samples, normalized to 10 kg of <2 mm table feed compared to the content of W (borate fusion), Mo, and Cu (aqua regia) in the <0.063 mm till matrix. Samples are listed according to increasing distance down-ice (southeast) of the Sisson W-Mo deposit.

Sample Number	Interpretation	Distance from Deposit (m)	W ppm	Mo ppm	Cu ppm	Scheelite 0.25-0.5 mm	Scheelite 0.5-1.0 mm	Scheelite 1.0-2.0 mm	Wolframite 0.25-0.5 mm	Molybdenite 0.25-0.5 mm	Chalcopyrite 0.25-0.5 mm	Arsenopyrite 0.25-0.5 mm	Sphalerite 0.25-0.5 mm	Bi minerals 0.25-0.5 mm	Pyrite 0.25-0.5 mm
11-MPB-520	background up-ice	-4000	6	0.5	16	0	0	0	0	0	0	0	0	0	0
11-MPB-521	background up-ice	-2250	4	0.6	23	2	0	0	0	0	0	0	0	0	0
11-MPB-507	overlying mineralization	0	816	63.0	310	4706	0	0	0	0	0	0	0	0	0
11-MPB-568	overlying mineralization	0	325	58.3	320	450	0	6	0	4	7	1	1	1	18
11-MPB-567	overlying mineralization	0	92	58.6	107	261	0	7	0	87	8	0	0	2	217
11-MPB-573	overlying mineralization	0	393	36.4	184	1852	0	0	0	4	0	0	0	4	2
12-MPB-1026	overlying mineralization	0	54	4.2	271	280	105	2	112	0	2	1	0	0	1
11-MPB-574	proximal down-ice	20	42	4.5	104	5	0	1	0	0	1	7	0	0	29
11-MPB-502	proximal down-ice	50	48	1.6	400	40	2	0	0	0	6	0	0	2	1200
11-MPB-562	proximal down-ice	100	14	1.1	84	404	0	1	0	0	1	0	0	1	10
11-MPB-511	proximal down-ice	400	65	3.7	134	36	0	2	0	0	2	0	0	0	0
CS-W08.5	proximal down-ice	650	51	3.5	165										
11-MPB-544	proximal down-ice	1100	75	8.3	179	49	0	1	0	0	1	0	0	0	0
11-MPB-519	proximal down-ice	1100	41	8.0	125	6	0	0	0	0	0	0	0	0	0
CS-VW09.5	distal down-ice	1500	26	5.4	76										
11-MPB-546	distal down-ice	2500	16	1.0	84	2	0	1	0	0	2	0	0	1	0
CS-W10A	distal down-ice	3200	14	2.0	93										
11-MPB-526	distal down-ice	3600	13	1.6	95	2	0	0	0	0	0	0	0	0	0
11-MPB-531	distal down-ice	4000	14	1.6	93	3	0	0	0	0	0	0	0	4	0
11-MPB-525	distal down-ice	4300	22	1.6	59	8	0	0	0	0	0	0	0	0	0
CS-WX11.5-2	distal down-ice	6200	11	1.1	71										
11-MPB-539	distal down-ice	10000	13	0.9	31	7	0	0	0	0	0	0	0	0	0
11-MPB-540	background down-ice	13000	4	6.0	35	0	0	0	0	0	0	0	0	0	0

The presence of coarse (0.5–2.0 mm) indicator minerals can be an indication of proximity (<1 km) to source.

Glacial dispersal of scheelite from the Sisson deposit is detectable in regional-scale surface till at least 14 km down-ice (southeast). A 2 km spacing of surface till samples, such as that used by the NBDEM for its regional till geochemistry program, is likely sufficiently dense to detect the glacial dispersal train from the Sisson deposit, as well as to identify its polymetallic nature.

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REFERENCES

Averill, S.A., 2001. The application of heavy indicator mineralogy in mineral exploration with emphasis on base metal indicators in glaciated metamorphic and plutonic terrains, *In:* Drift Exploration in Glaciated Terrain, (eds.) M.B. McClenaghan, P.T. Bobrowsky, G.E.M. Hall, and S.J. Cook; Geological Society of London, Special Publication 185, p. 69–81.

Brundin, N.H. and Bergström, J., 1977. Regional prospecting for ores based on heavy minerals in glacial till; Journal of Geochemical Exploration. v. 7, p. 1–19.

Coker, W.B., Robertson J., and Snow, R.J., 1988. Till geochemistry at the Great Gull scheelite prospects, Newfoundland, Canada: a case history in orientation and discovery. *In:* Prospecting in Areas of Glaciated Terrain—1988, (ed.) D.R. MacDonald; Canadian Institute of Mining and Metallurgy, p. 587–598.

de Smeth, J.B., Rao, K.S., and Schuling, R.D., 1985. Gold-scheelite mineralization in the Veligallu schist belt, Andhra Pradesh, India; Economic Geology, v. 80, p. 1996–2000.

Fernández-Turiel, J.L., Durán, M.E., Querol, X., and López-Soler, A., 1992. Comparison between analytical and mineralometric methods in regional scheelite exploration; Journal of Geochemical Exploration, v. 43, p. 205–211.

Fyffe, L.R., Thorne, K., Dunning, G.R., and Martin, D.A., 2008. U-Pb geochronology of the Sisson Brook granite porphyry, York County, west-central New Brunswick, *In:* Geological Investigations in New Brunswick for 2007, (ed.) G.L. Martin; New Brunswick Department of Natural Resources, Mineral Resource Report 2008-1, p. 35–54.

Fyffe, L.R., Seaman, A., Thorne, K., and Martin, D.A., 2010. Part 1: Sisson Brook W-Mo-Cu deposit, *In:* Polymetallic deposits of Sisson Brook and Mount Pleasant, New Brunswick, Canada, (compilers) L.R. Fyffe and K. Thorne; New Brunswick Department Natural Resources, Field Guide No. 3, p. 7–33.

Hallenstein, C.P., Pedersen, J.L., and Stendal, H., 1981. Exploration for scheelite in East Greenland– a case study; Journal of Geochemical Exploration, v. 15, p. 381–392.

Johansson, K., Keinänen, V., and Lehmuspelto, P., 1986. Geochemical exploration of tungsten in glaciogenic deposits in Soretiapulju, Western Finnish Lapland. In: Prospecting in Areas of Glaciated Terrain—1986; Institute of Mining and Metallurgy. p. 61–68.

Lindmark, B., 1977. Till-sampling methods used in exploration for scheelite in Kaustinen, Finland, *In:* Prospecting in Areas of Glaciated Terrain—1977, (ed.) G.R. Davis; Institute of Mining and Metallurgy, p. 46–48.

Marr, J.M., 2009. Sisson Brook tungsten molybdenum deposit, New Brunswick, preliminary economic assessment (2009 Technical and Economic Update); September 16th, 2009, National Instrument 43-101 technical report by Geodex Minerals Ltd.

Maurice, Y.T., 1986. Interpretation of a reconnaissance geochemical heavy mineral survey in the Eastern Townships of Quebec, In: Current Research, Part A; Geological Survey of Canada, Paper 86-1A, p. 307–317.

McClenaghan, M.B., 2011. Overview of common processing methods for recovery of indicator minerals from sediment and bedrock in mineral exploration; Geochemistry: Exploration, Environment, Analysis, v. 11, p. 265–278.

McClenaghan, M.B., Budulan, G., Averill, S.A., Layton-Matthews, D., and Parkhill, M.A., 2012. Indicator mineral abundance data for bedrock and till samples from the Halfmile Lake Zn-Pb-Cu volcanogenic massive sulphide deposit, Bathurst Mining Camp, New Brunswick; Geological Survey of Canada, Open File 7076. doi:10.4095/291437

McClenaghan, M.B., Parkhill, M.A., Averill, S.A., Pronk, A.G., Seaman, A.A., Boldon, R., McCurdy, M.W., and Rice, J.M., 2013a. Indicator mineral abundance data for bedrock, till, and stream sediment samples from the Sisson W-Mo deposit, New Brunswick; Geological Survey of Canada, Open File 7387. doi:10.4095/292670

McClenaghan, M.B., Parkhill, M.A., Averill, S.A., and Kjarsgaard, I.M., 2013b. Indicator mineral signatures of the Sisson W-Mo deposit, New Brunswick: part 1 bedrock samples; Geological Survey of Canada, Open File 7431. doi:10.4095/292805

McClenaghan, M.B., Parkhill, M.A., Seaman, A.A., Pronk, A.G., Pyne, M., Rice, J.M., and Hashmi, S., 2013c. Till geochemical signatures of the Sisson W-Mo deposit, New Brunswick; Geological Survey of Canada, Open File 7430. doi:10.4095/292837

Nast, H.J. and Williams-Jones, A.E., 1991. The role of water-rock interaction and fluid evolution in the forming of the porphyry-related Sisson Brook W-Cu-Mo deposit, New Brunswick; Economic Geology, v. 86, p. 302–317.

Nikkarinen, M. and Björklund, A.; 1976. Kaustinen: The use of till in tungsten prospecting; Journal of Geochemical Exploration, v. 21, p. 247–248.

Özcan, A. and Çağatay, M.N., 1989. Tungsten exploration in semi-arid environment: Central Anatolian massif, Turkey; Journal of Geochemical Exploration, v. 31, p. 185–199.

Oviatt, N.M., McClenaghan, M.B., Paulen, R.C., Gleeson, S.A., Averill, S.A., and Paradis, S.; 2013. Indicator minerals in till and bedrock samples from the Pine Point Mississippi Valley-Type (MVT) district, Northwest Territories; Geological Survey of Canada, Open File 7432. doi:10.4095/292913

Petersen, L.R. and Stendal, H., 1987. Tungsten exploration in the Valnesfjord region, Nordland, northern Norway; Journal of Geochemical Exploration, v. 29, p. 151–163

Peuraneimi, V., 1992. Hieronmaki: W, Sn, Cu, and Zn concentrations of till near a scheelite mineralization in hilly region, *In:* Handbook of Exploration Geochemistry: Regolith Exploration Geochemistry in Arctic and Temperate Terrains Volume 5, (eds.) K. Kauranne, R. Salminen, and V-P. Salonen; Elsevier, p. 277–282.

Plouffe, A., McClenaghan, M.B., Paulen, R.C., McMartin, I., Campbell, J.E., and Spirito, W.A., in press. Processing of unconsolidated glacial sediments for the recovery of indicator minerals: protocols used at the Geological Survey of Canada; Geochemistry: Exploration, Environment, Analysis.

Rennie, D.W., 2012. Technical report on the Sisson Project, New Brunswick, Canada; June 29, 2012, National Instrument 43-101 technical report by Northcliff Resources Ltd.

Salminen, R. and Hartikainen, A., 1986. Tracing gold, molybdenum and tungsten mineralization by use of a step by step geochemical study in Ilomantsi, eastern Finland, In: Prospecting In Areas of Glaciated Terrain-1986; Institution of Mining and Metallurgy, London. p. 201–209.

Seaman, A.A., 2002. Till geochemistry of the central and eastern parts of the Coldstream (NTS 21J/06) map area, York and Carleton counties, New Brunswick; New Brunswick Department of Natural Resources, Minerals, Policy and Planning Division, Open File 2002-5.

Seaman, A.A., 2003. Follow up till geochemistry, Coldstream (NTS21J/06) map area and part of the adjacent Napadogan (NTS 21J/07) map area, York and Carelton counties, New Brunswick; New Brunswick Department of Natural Resources, Minerals, Policy and Planning Division, Open File 2003-11.

Seaman, A.A., 2007. Reconnaissance till geochemistry of NTS 21 J/01, J/02, J/07, and J/08 map areas (parts of York, Sunbury, Northumberland, and Queens counties), central New Brunswick: site and geochemical data; New Brunswick Department of Natural Resources, Minerals, Policy and Planning Division, Open File 2007-8.

Seaman, A.A. and McCoy, S.M., 2008. Multiple Wisconsinan tills in the Sisson Brook exploration trench of Geodex Minerals Ltd., York County, west-central New Brunswick, *In:* Geological Investigations in New Brunswick for 2007, (ed.) G.L. Martin; New Brunswick Department of Natural Resources; Minerals, Policy and Planning Division, Mineral Resource Report 2008-1, p. 1–34.

Smith, E.A. and Fyffe, L.R. (compilers), 2006a. Bedrock geology of the Burtts Corner area (NTS 21 J/02), York County, New Brunswick, New Brunswick Department of Natural Resources, Minerals, Policy and Planning Division, Map Plate 2006-3.

Smith, E.A. and Fyffe, L.R. (compilers), 2006b. Bedrock Geology of the Millville Area (NTS 21 J/03), York and Carleton Counties, New Brunswick; New Brunswick Department of Natural Resources, Minerals, Policy and Planning Division, Map Plate 2006-4.

Smith, E.A. and Fyffe, L.R. (compilers), 2006c. Bedrock Geology of the Coldstream Area (NTS 21 J/06), York and Carleton counties, New Brunswick, New Brunswick Department of Natural Resources, Minerals, Policy and Planning Division, Map Plate 2006-7.

Smith, E.A. and Fyffe, L.R. (compilers), 2006d. Bedrock geology of the Napadogan area (NTS 21 J/07), York and Carleton Counties, New Brunswick; New Brunswick Department of Natural Resources, Minerals, Policy and Planning Division, Map Plate 2006-8.

Snow, R.J. and Coker, W.B., 1987. Overburden geochemistry related to W-Cu-Mo mineralization at Sisson Brook, New Brunswick, Canada: an example of short- and long-distance glacial dispersal, *In:* Geochemical Exploration 1985, (ed.) R.G. Garrett; Journal of Geochemical Exploration, v. 28, p. 353–368.

Steiger, R., 1977. Prospecting for lithium and tungsten in Ireland, *In:* Prospecting in Areas of Glaciated Terrain—1977, (ed.) G.R. Davis; Institute of Mining and Metallurgy, p. 14–24.

Stendal, H., 1978. Heavy minerals in stream sediments, southwest Norway; Journal of Geochemical Exploration, v. 10, p. 91–102.

Stea, R.R. and O'Reilly, G.A., 1982. Till geochemistry of the Meguma Terrane in Nova Scotia and its metallogenic implications, *In:* Prospecting in Areas of Glaciated Terrain-1982; Institute of Mining and Metallurgy, p. 82–104.

Toverud, O., 1984. Dispersal of tungsten in glacial drift and humus in Bergslagen, south central Sweden; Journal of Geochemical Exploration, v. 21, p. 261–272.

Wilson, R.A., 2007. Bedrock geology of the Nepisiguit Lakes area (NTS 21O/7), Restigouche and Northumberland counties, New Brunswick; New Brunswick Department of Natural Resources, Map Plate 2007-32.

Zeschke, G., 1961. Prospecting for ore deposits by panning heavy minerals from river sands; Economic Geology, v. 56, p. 1250–1257.

Appendix A. Sample location data for the 2011 and 2012 GSC till samples

Samples	Material	Status	Distance from mineralization	Easting	Northing	Location	Type of site	Depth from (m)	to (m)	<0.063 mm geochem sample?	Heavy mineral sample ?	HMC processed ?	Striation azimuth	Notes on stratigraphy/ lithology
				UTM 19T NTS sheet 21J/06 Datum NAD83										
11-MPB-striae site1	NA	striation site		651164	5138910	HH11-03	outcrop						149	no sense
11-MPB-striae site2	NA	striation site		651348	5138488		outcrop						147	no sense
11-MPB-501	blank	Bathurst blank 008										yes		
11-MPB-502	till		overlying	650144	5136006	drill pad prop 24	backhoe trench	1.1	1.3	yes	yes	yes		1.0 m sandy ablation till at surface
11-MPB-503	till		overlying	650209	5136227	drill pad prop 18	backhoe trench	2.0	2.3	yes	yes	yes		
11-MPB-504	till	field duplicate of 503	overlying	650209	5136227	drill pad prop 18	backhoe trench	2.5	2.8	yes	yes	yes		
11-MPB-505	till		overlying	650209	5136227	drill pad prop 18	backhoe trench	0.9	1.1	yes	yes	yes		
11-MPB-507	till		overlying	659667	5124482	drill pad DUAL_15	backhoe trench	2.2	2.5	yes	yes	yes		
11-MPB-508	till		1 km down-ice	650318	5135189	Seaman CS-V09	backhoe trench	1.7	2.0	yes	yes	yes		
11-MPB-509	till		1 km down-ice	650318	5135189	Seaman CS-V09	backhoe trench	0.7	1.0	yes	yes	yes		
11-MPB-510	till		just South	649441	5135096	T junction in trail	backhoe trench	0.5	0.6	yes	yes	yes		0.1 m sandy ablation till at surface
11-MPB-511	till		Nash ridge	650621	5136083	Nashwaak ridge road	backhoe trench	0.8	1.0	yes	yes	yes		
11-MPB-513	till		overlying	649539	5136344	drill pad prop 28	backhoe trench	1.5	1.7	yes	yes	yes		0.5 m sandy ablation at surface
11-MPB-514	till		overlying	649812	5136536	drill pad prop 13	backhoe trench	1.5	1.7	yes	yes	yes		
11-MPB-517	till		overlying	650168	5136486	drill pad MET_26	backhoe trench	0.7	1.0	yes	yes	yes		
11-MPB-518	till		E side Nash Ridge	651430	5136387	E side Nashawaak ridge	backhoe trench	1.5	1.8	yes	yes	yes		
11-MPB-519	till		E side Nash Ridge	651442	5135915	E side Nashawaak ridge	backhoe trench	1.8	2.0	yes	yes	yes		
11-MPB-520	till		3 km up-ice	648194	5140992	Seaman site CV-T06	backhoe trench	0.8	0.9	yes	yes	yes		
11-MPB-521	till		2 km up-ice	647922	5138265	HH11-06 drill pad	backhoe trench	1.2	1.4	yes	yes	yes		
11-MPB-522	till	field duplicate of 521	2 km up-ice	647922	5138265	HH11-06 drill pad	backhoe trench	1.2	1.4	yes	yes	yes		
11-MPB-523	till		overlying	649815	5136045	drill pad prop 23	backhoe trench	2.3	2.5	yes	yes	yes		0.5 m sandy ablation at surface
11-MPB-524	till		4 km due south	650127	5133483	Seaman CS-V10a	backhoe trench	0.9	1.0	yes	yes	yes		
11-MPB-525	till		8 km down-ice	652925	5132444	Seaman CS-WX10.5	backhoe trench	1.0	1.2	yes	yes	yes		
11-MPB-526	till		8 km down-ice	653133	5133536	N. of Seaman CS-WX10.5	backhoe trench	0.4	0.6	yes	yes	yes		
11-MPB-527	till		8 km down-ice	654729	5129639	close to Seaman ND-B12b	backhoe trench	0.8	1.0	yes	yes	yes		
11-MPB-528	till		6 km down-ice	652460	5131172	close to Seaman CS-W11	backhoe trench	0.5	0.7	yes	yes	yes		
11-MPB-529	till		6 km down-ice	652000	5131185	Seaman CS-W11	backhoe trench	0.7	0.9	yes	yes	yes		
11-MPB-530	till		5 km down-ice	650900	5132236	Seaman CS-VW10.5	backhoe trench	0.6	0.8	yes	yes	yes		
11-MPB-531	till		5 km down-ice	651653	5132671	Seaman CS-W10.5	backhoe trench	1.1	1.3	yes	yes	yes		
11-MPB-532	till		overlying	650555	5136870	SB-11-016	drill core	11.3	15.0	yes	yes	yes		
11-MPB-533	till		overlying	650555	5136870	SB-11-016	drill core	9.7	11.3	yes	yes	yes		
11-MPB-534	till		overlying	650555	5136870	SB-11-016	drill core	4.4	9.7	yes	yes	yes		
11-MPB-535	till		overlying	650283	5136754	SB-11-018	drill core	7.5	10.3	yes	yes	yes		
11-MPB-536	till		overlying	650508	5136727	SB-11-007	drill core	14.0	15.3	yes	yes	yes		
11-MPB-539	till		10 km down-ice	656426	5127412	test pit MP-01	backhoe trench	0.9	1.0	yes	yes	yes		
11-MPB-540	till		12 km down-ice	658670	5125194	test pit MP-06	backhoe trench	0.9	1.1	yes	yes	yes		
11-MPB-543	till		overlying	650493	5136728	drill pad MET-18	backhoe trench	2.3	2.5	yes	yes	yes		2.0 m sandy ablation at surface
11-MPB-544	till		Nash ridge	650933	5135278	road cut on skidder trail	backhoe trench	0.5	0.6	yes	yes	yes		
11-MPB-545	till		3 km down-ice	651612	5133445	Seaman CS-W10b	backhoe trench	0.6	0.8	yes	yes	yes		
11-MPB-546	till		3 km down-ice	651103	5133461	Seaman CS-VW10	backhoe trench	0.7	0.9	yes	yes	yes		
11-MPB-547	till		8 km down-ice	655205	5128585	Seaman ND-B12b	backhoe trench	1.3	1.5	yes	yes	yes		
11-MPB-548	till		overlying	650621	5136945	drill pad MET-09	backhoe trench	2.3	2.5	yes	yes	yes		
11-MPB-551	till		overlying	649557	5136745	testpit TP-11-78	backhoe trench	2.0	2.0	yes	yes	yes		
11-MPB-552	till		overlying	649689	5136860	test pit TP-11-77	backhoe trench	3.9	4.0	yes	yes	yes		
11-MPB-553	till		overlying	649739	5136450	test pit TP-11-80	backhoe trench	1.3	1.5	yes	yes	yes		
11-MPB-555	till		overlying	650098	5137401	Seaman CS-08a	backhoe trench	0.8	1.1	yes	yes	yes		
11-MPB-556	till	field duplicate of 555	overlying	650098	5137401	Seaman CS-08a	backhoe trench	0.8	1.1	yes	yes	yes		
11-MPB-558	till		overlying	650681	5136677	drill pad Prop-09	backhoe trench	1.9	2.2	yes	yes	yes		

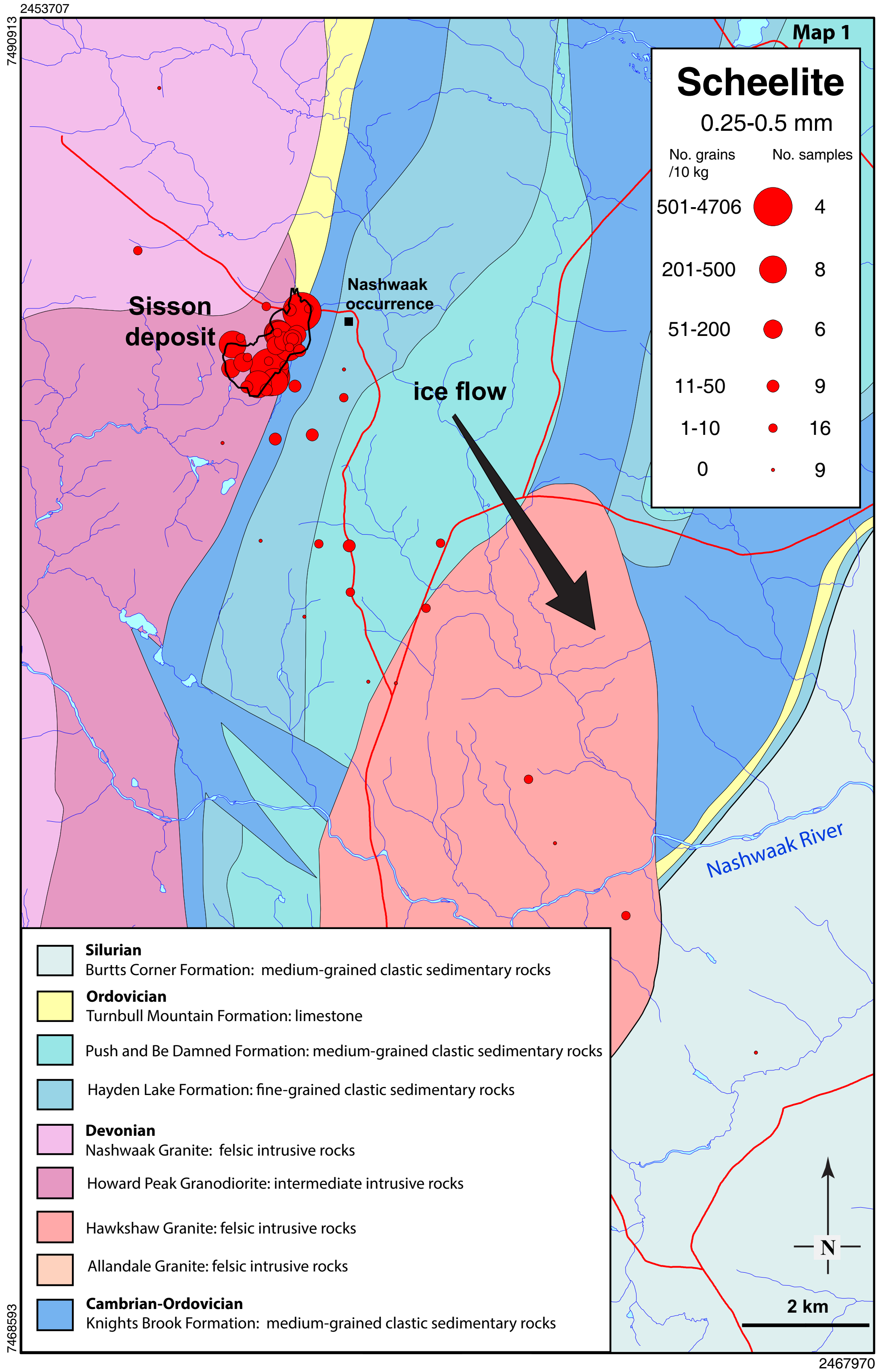
Appendix A continued.

Samples	Material	Status	Distance from mineralization	Easting (UTM 19T, NTS sheet 21J/06, Datum NAD83)	Northing (UTM 19T, NTS sheet 21J/06, Datum NAD83)	Location	Type of site	Depth from (m)	Depth to (m)	<0.063 mm geochem sample?	Heavy mineral sample ?	HMC processed ?	Striation azimuth	Notes on stratigraphy/ lithology
11-MPB-560	blank	Bathurst blank 114										yes		
11-MPB-561	blank	Bathurst blank 583										yes		
11-MPB-562	till		overlying	650272	5136143	drill pad Prop 31	backhoe trench	1.2	1.5	yes	yes	yes		
11-MPB-566	till		overlying	650300	5136968	Sisson main trench, NE corner	trench wall section	1.5	2.5	yes	yes	yes		
11-MPB-567	till		overlying	650304	5136957	Sisson main trench, NE corner	trench wall section	1.5	1.8	yes	yes	yes		Caledonia till
11-MPB-568	till		overlying	650309	5136937	Sisson main trench, SE corner	trench wall section	3.8	4.0	yes	yes	yes		Caledonia till
11-MPB-569	till		overlying	650337	5136936	SE of Sisson main trench	backhoe trench	2.3	2.5	yes	yes	yes		Caledonia till
11-MPB-572	till		overlying	650002	5136093	TP-11-82	backhoe trench	2.5	2.5	yes	yes	yes		Caledonia till
11-MPB-573	till		overlying	650181	5136377	TP11-81	backhoe trench	2.4	2.4	yes	yes	yes		
11-MPB-574	till		overlying	650428	5136422	Prop 30/TP-02	backhoe trench	2.1	2.1	yes	yes	yes		
11-MPB-575	till		overlying	650409	5136829	TP-03	backhoe trench	0.5	1.2	yes	yes	yes		
11-MPB-576	till		overlying	650810	5137385	CP11-121	backhoe trench	3.4	3.4	yes	yes	yes		
11-MPB-577	till		overlying	650699	5137329	CP-11-110/TP-14	backhoe trench	2.2	2.2	yes	yes	yes		
11-MPB-578	till		overlying	650499	5137352	CP-108/TP-13	backhoe trench	2.2	2.2	yes	yes	yes		
11-MPB-579	till		overlying	650555	5136870	SB-11-016	ddh	19.8	22.5	no	yes	yes		
11-MPB-580	blank	Bathurst blank 059										yes		
12-MPB-1026*	till		overlying	650633	5137391	Discovery Zone subcrop	trench wall section	0.8	1.0	yes	yes	yes		

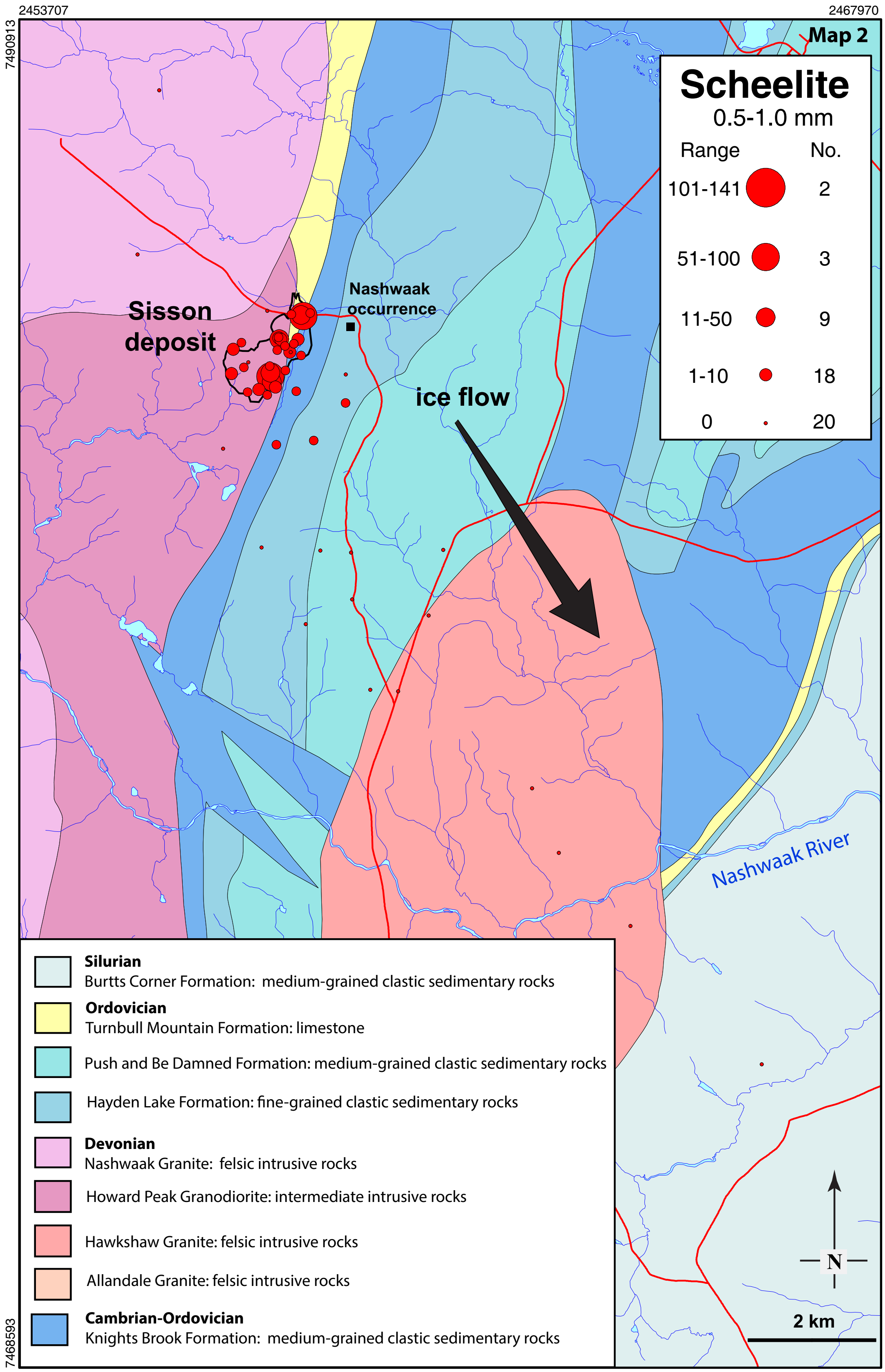
*All samples collected in 2011 with the exception of sample 12-MPB-1026, which was collected in 2012

Sample	Type of sample	Lithology	Easting (UTM 19T, NTS sheet 21J/06, Datum NAD83)	Northing (UTM 19T, NTS sheet 21J/06, Datum NAD83)	Latitude	Longitude	Location	Depth from (m)	Depth to (m)	Bedrock lithoogy
11-MPB-R01	drill core	bedrock	650053	5135982			SB-09-15	70.7	71.8	high-grade mineralization
11-MPB-R02	drill core	bedrock	650053	5135982			SB-09-15	121.5	122.8	quartz feldspar porphyry
11-MPB-R03	drill core	bedrock	650053	5135982			SB-09-15	201.5	202.1	gabbro
11-MPB-R04	drill core	bedrock	650717	5136853			SB-09-05	205.6	206.0	biotite wacke
11-MPB-R05	drill core	bedrock	650421	5137244			SB-09-12	81.3		mineralization
11-MPB-R06	drill core	bedrock	650421	5137244			SB-09-12	112.3	113.0	felsic tuff
11-MPB-R07	drill core	bedrock	650483	5136646			SB-09-25	38.5	39.3	mafic tuff
11-MPB-R08	drill core	bedrock	650469	5136643			SB-08-03	91.0	92.0	Howard's Peak granite
11-MPB-R09	drill core	bedrock	650092	5136660			SB-10-005	248.7	249.1	Turnball Mtn Fm mafic crystal tuff
11-MPB-R10	grab sample	bedrock			46°30'45.2"	66°59'39.2"	borrow pit			Nashwaak granite
11-MPB-R11	grab sample	bedrock			46°28'45.2"	67°0247.3"	outcrop north of Deersdale			altered Nashwaak granite

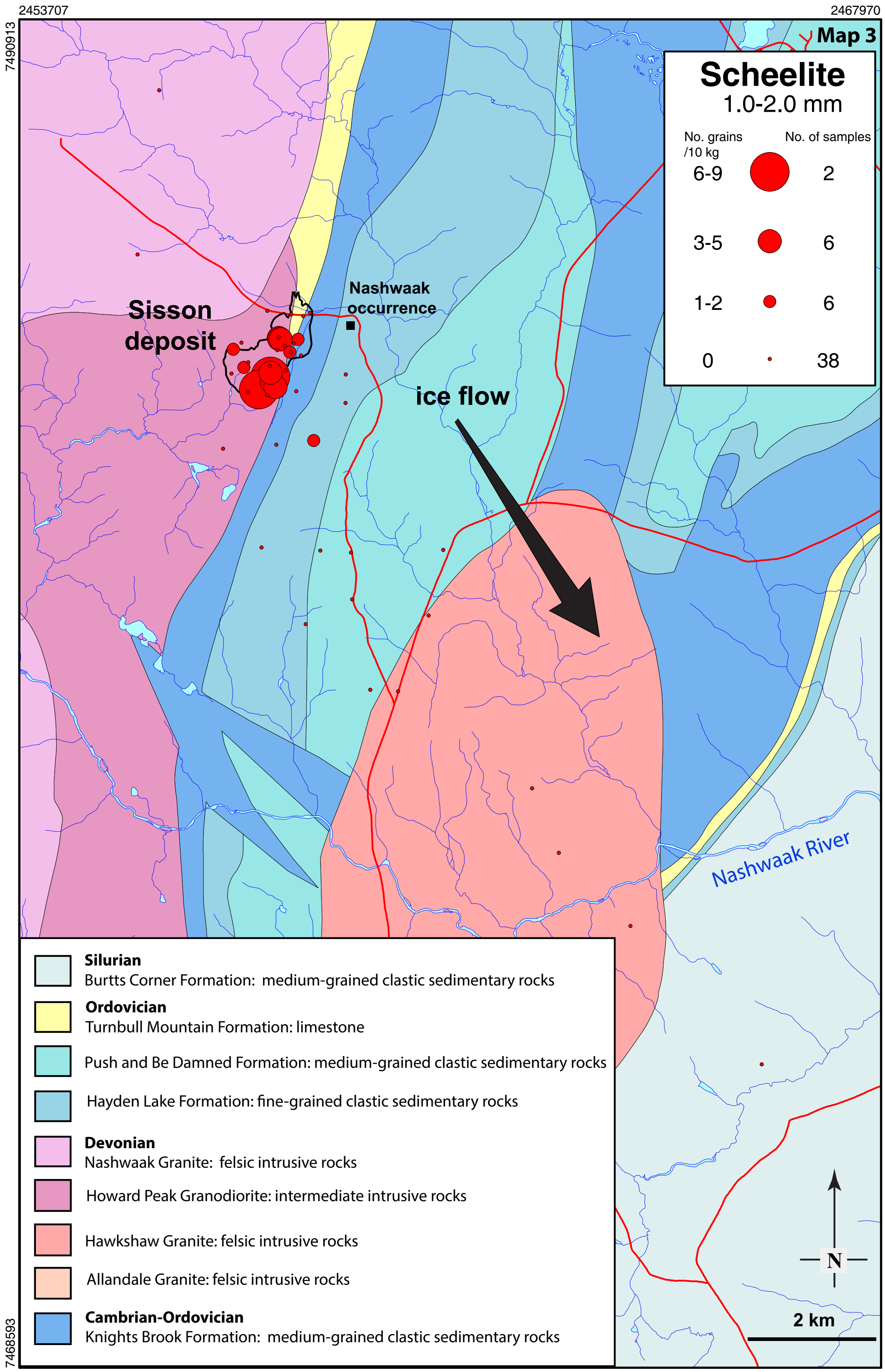
Appendix B. Proportional dot maps showing indicator mineral abundance in the non-ferromagnetic heavy mineral fraction of till normalized to 10 kg <2 mm table feed. Bedrock geology modified from Smith and Fyffe (2006a-d). Deposit subcrop outline in black from Rennie (2012).



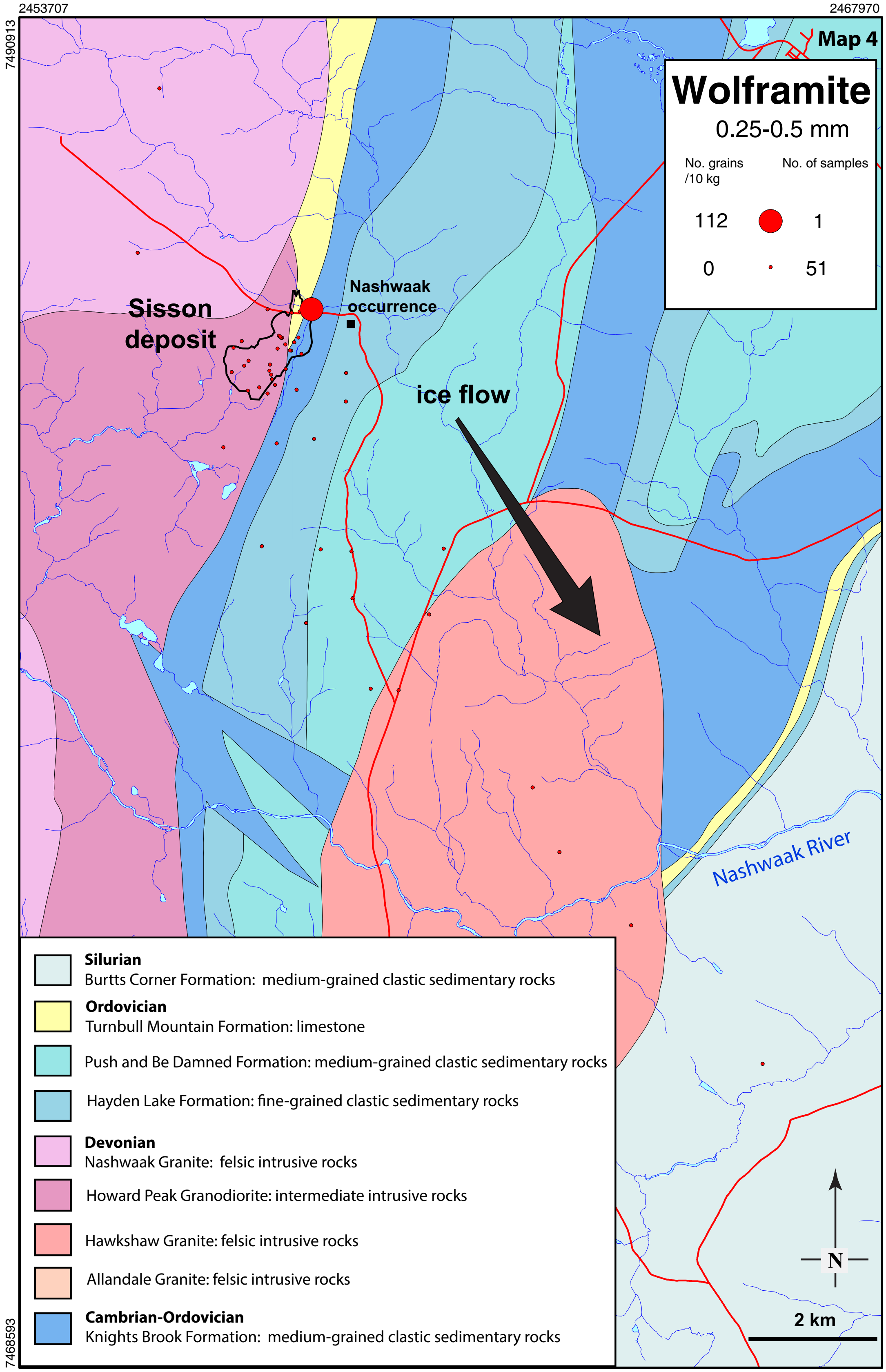
Appendix B continued.



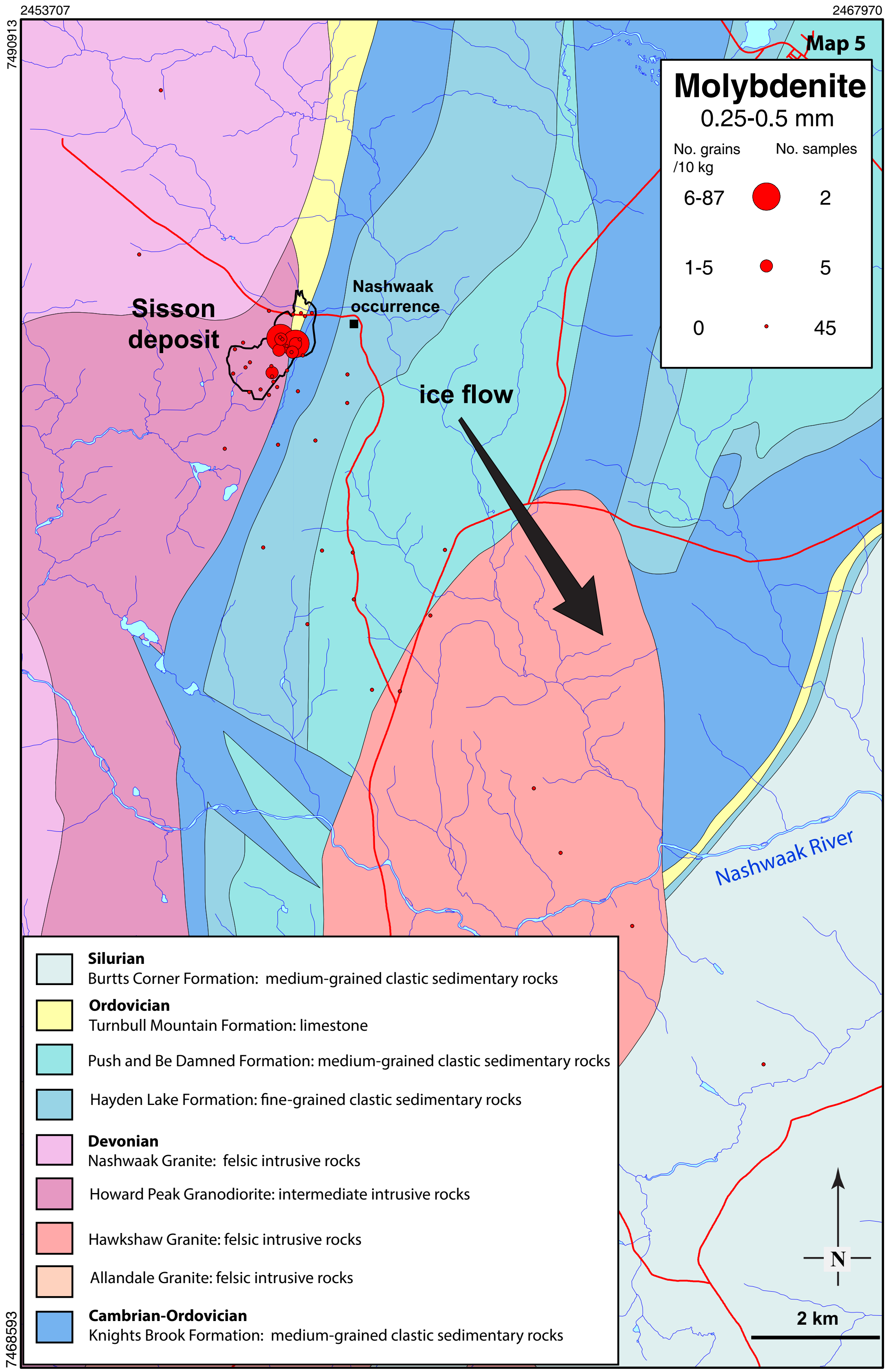
Appendix B continued.



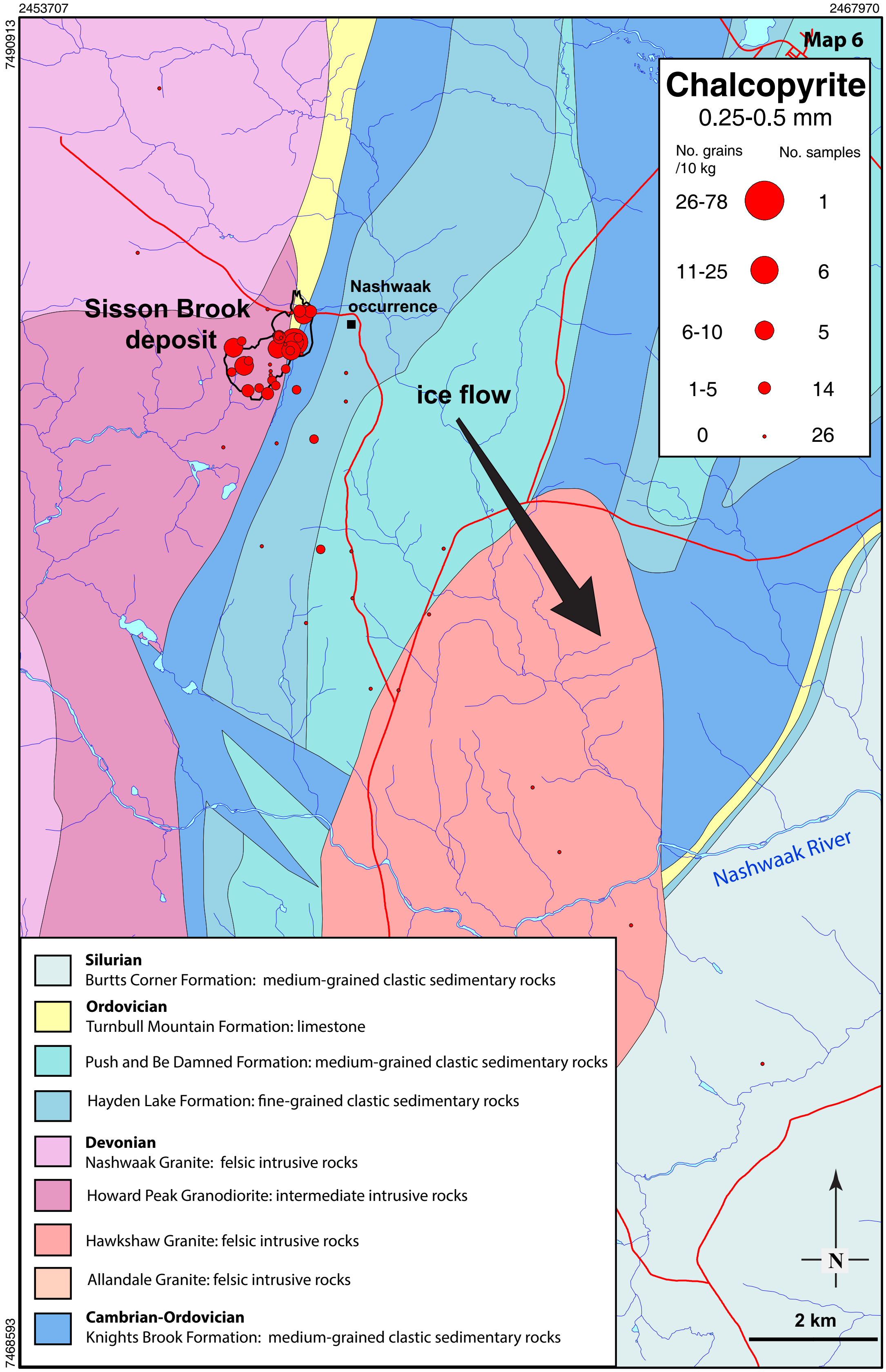
Appendix B continued.



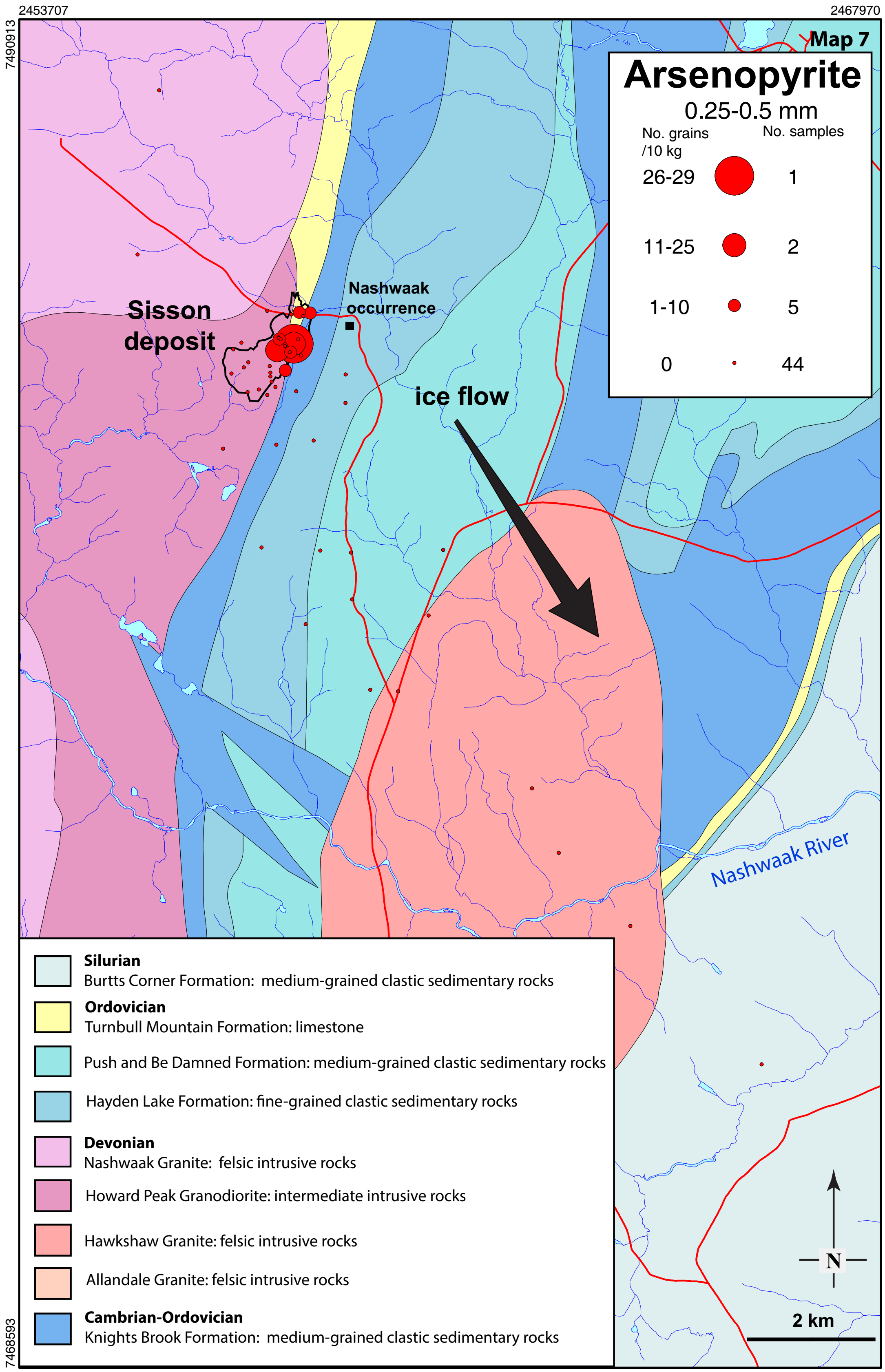
Appendix B continued.



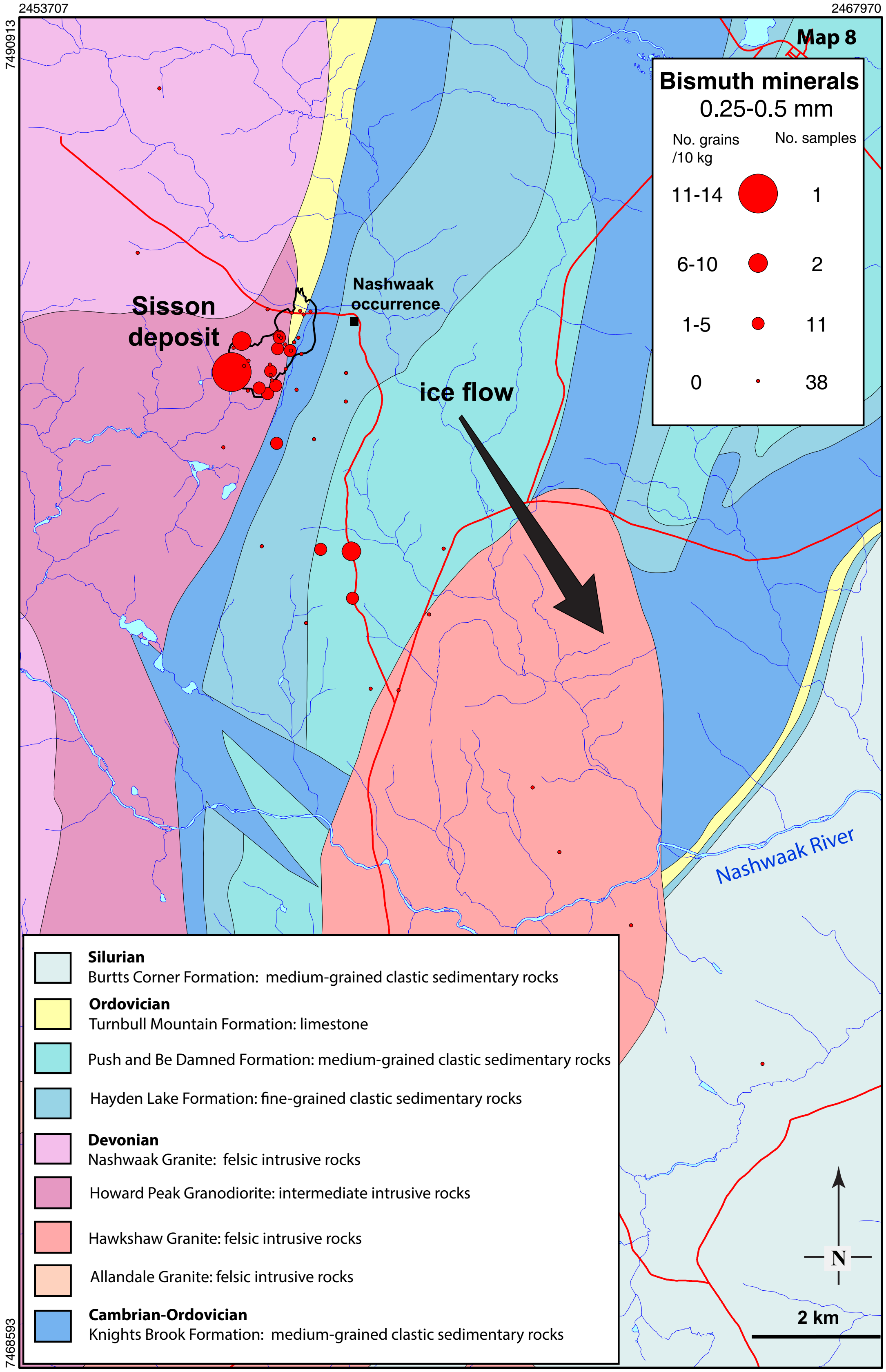
Appendix B continued.



Appendix B continued.



Appendix B continued.



Appendix B continued.