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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 Mount Pleasant Sn-W-Mo-Bi-In deposit, New Brunswick

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ABSTRACT

An indicator mineral study was carried out around the Mount Pleasant Sn-W-Mo-Bi-In deposit 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 one of the first systematic case studies around a major Sn-W 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 cassiterite and wolframite.

Indicator minerals recovered from till at the Mount Pleasant deposit include the main ore minerals, cassiterite, wolframite, and molybdenite, as well as fluorite, topaz, galena, arsenopyrite, and loellingite in the 0.25–0.5 mm, >3.2 SG fraction. Useful indicator minerals in till also include secondary Pb sulphate minerals beudantite ($PbFe_3(AsO_4)(SO_4)(OH)_6$) and anglesite ($Pb(SO_4)$), which formed from the oxidation and weathering of galena.

INTRODUCTION

Cassiterite is a dense hard metal that has a low melting point, is malleable is resistant to corrosion, has the ability to alloy with other metals, and is relatively easy to recycle. These qualities that make it optimal for a wide range of industrial applications, including tinplating for food packaging, Sn solder or coatings of In-Sn oxide on liquid crystal displays in televisions, cell phones, and other electronics, and in the production of bronze, pewter, and die-casting alloys (Adex Mining Inc., 2015; USGS, 2015). Placer deposits in southeast Asia supply approximately 50% of the world's Sn production. Canada currently has no producing Sn mines, though there have been some in the past (e.g. East Kemptville Sn mine, Nova Scotia).

Cassiterite (SnO_2) is the main ore mineral of Sn, although small quantities of Sn may also be recovered from stannite, cylindrite, frankeite, canfieldite, and teallite (USGS, 2015). Cassiterite is extremely resistant to both chemical and physical weathering, and readily survives glacial transport and subsequent postglacial weathering and oxidation. These features, combined with its hardness and high density, make it an ideal indicator mineral for prospecting for Sn deposits in glaciated terrain. The presence of cassiterite in till has been reported in the literature (e.g. Mattila and Peuraniemi, 1980; Peuraniemi et al., 1984; Peuraniemi and Heinanen, 1985; Peuraniemi, 1987; Rogers and Garrett, 1987; Thomas et al., 1987), however, these reports did not use the modern indicator mineral methods that are available today.

The Mount Pleasant deposit was chosen as a Sn indicator mineral test site because the deposit (1) is known to contain cassiterite; (2) bedrock and surficial geology are well known; (3) subcrops and thus was exposed to direct glacial erosion; (4) is easily accessible by road; and (5) has a previously identified till geochemical dispersal train down-ice (Szabo et al., 1975) and thus Sn-rich till should be available for sampling. The study at Mount Pleasant is one of two conducted by the Geological Survey of Canada (GSC) through its Targeted Geoscience Initiative 4 (TGI-4) Program (2010–2015) in collaboration with the New Brunswick Department of Energy and Mines (NBDEM). The other study was undertaken at the Sisson W-Mo deposit (McClenaghan et al., 2014a) to document its indicator mineral signatures.

The specific objectives of this research project are (1) to determine indicator minerals signatures that are indicative of intrusion-hosted polymetallic Sn deposits; and (2) to establish practical methods for recovery and identification of indicator minerals from glacial sediments that can be routinely applied when exploring for Sn in glaciated terrain. The purpose of this open file is to report the indicator mineral data for till samples collected around the deposit in 2012. Sampling was not intended to outline the glacial dispersal train, but to document the indicator minerals that are present within the known geochemical dispersal train at varying distances down-ice. Unedited indicator mineral data for these till samples have been published in GSC Open File 7573 (McClenaghan et al., 2014b). Bedrock indicator mineral data have been published in GSC Open File 7721 (McClenaghan et al., 2015a). Till matrix geochemical data for these samples have been published in GSC Open File 7722 (McClenaghan et al., 2015b).

LOCATION AND ACCESS

The Mount Pleasant deposit is in southern New Brunswick (Fig. 1) at 45°26'N and 66°49'W in the McDougall Lake map area (NTS 21 G/07). The deposit is located 60 km south of Fredericton and is easily accessed by a mine road that extends northwest from Highway 785.

GEOLOGY

Bedrock geology

The bedrock geology of the Mount Pleasant area is summarized below from several sources, including Hosking (1963), Petruk (1972, 1973), Kooiman et al. (1986), Invemo and Hutchinson (2004), Sinclair et al. (2006), and McCutcheon et al. (2010, 2013). The deposit is in the Appalachian Orogen within two subvolcanic intrusions of the Late Devonian Mount Pleasant Caldera Complex, along the north flank of the Saint George Batholith (Fig. 2). The McDougall Brook Granitic Suite is related to the early stages of caldera development, and the Mount Pleasant Granitic Suite to the late stages of caldera development. The deposit consists of Sn, W, and Mo mineralization that is genetically related to highly evolved granite of the Mount Pleasant Granitic Suite (Granites I, II, III), which is enriched in incompatible elements F, Li, Rb, Cs, U, Th, and Nb. Granite I and the related breccia hosts W-Mo-Bi mineralization and Granite II hosts Sn-In mineralization (Figs. 3, 4). The deposit consists of three mineralized zones, which are, from north to south, the North Zone, the Saddle Zone, and the Fire Tower Zone, the latter named for its proximity to a fire tower. Both the North and Fire Tower zones outcrop or subcrop beneath till (Fig. 3), and thus likely contributed mineralized debris to overriding glaciers. These two zones are described below.

The North Zone consists of older W-Mo mineralization and younger Sn-In mineralization, some of which occurs at or near surface (Fig. 4). The Sn-In zones contain cassiterite, arsenopyrite, loellingite, sphalerite, and chalcopyrite, as well as the other sulphide minerals listed in Table 1. The Fire Tower Zone, 1200 m to the

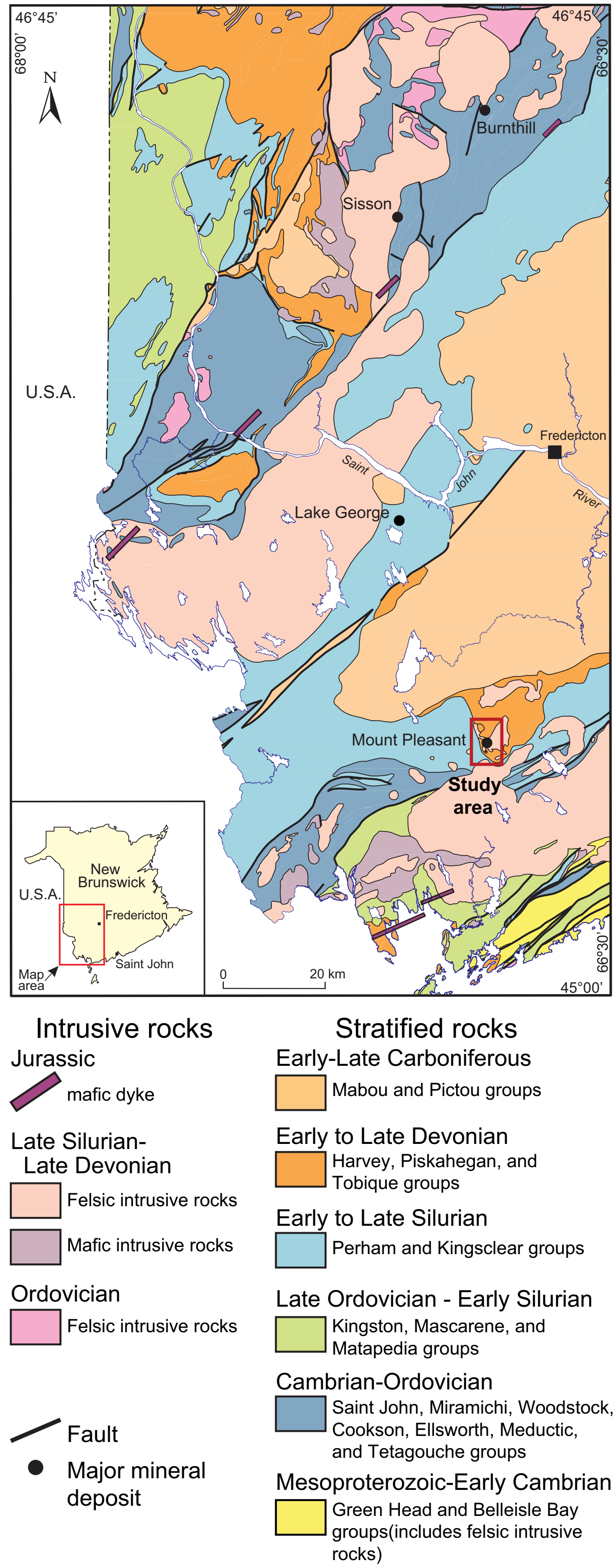

Figure 1. Bedrock geology of west-central and southern New Brunswick showing the location of the Mount Pleasant Sn-W-Mo-Bi-In deposit and other significant deposits (modified from McCutcheon et al., 2010).

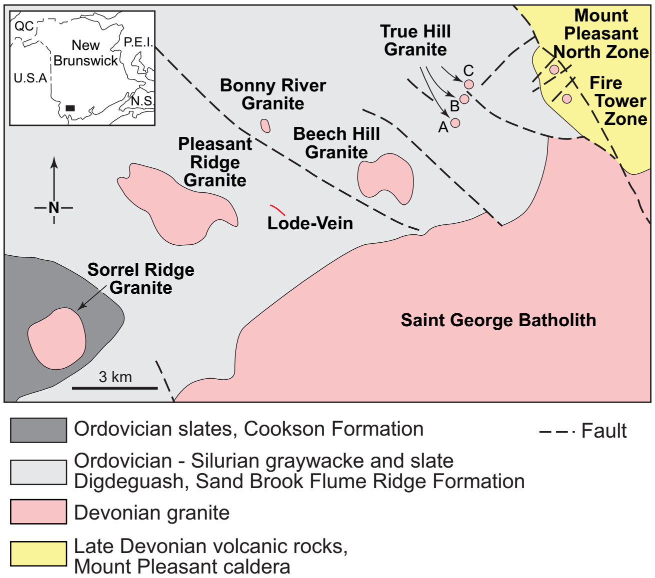

Figure 2. Bedrock geology of the Mount Pleasant area showing location of nearby Devonian granite (modified from Lentz, 1994).

south, contains predominantly large, low-grade W-Mo deposits with some small In-bearing Sn-base metal resources. The main ore minerals in the Fire Tower Zone are wolframite and molybdenite, with minor native bismuth and bismuthinite. Gangue minerals include cassiterite, arsenopyrite, and loellingite, as well as quartz, topaz, and fluorite. The Fire Tower Zone also contains small In-bearing Sn-base metal zones in irregular veins and breccias, consisting mainly of cassiterite and wolframite along with the sulphide minerals listed in Table 1. Indium in the Mount Pleasant deposit occurs mainly as a solid solution between sphalerite and roquesite, but is also present in chalcopyrite and stannite (Petruk, 1972; Sinclair et al., 2006). The ore minerals are, in places, very fine grained and cannot be seen in hand specimen (Petruk, 1972, 1973).

The NI 43-101 resource estimate for the Fire Tower Zone consists of an indicated resource of 13.489 million tonnes at 0.33% WO_3, 0.21% MoS_2, 0.57 % As, and 0.06% Bi, as well as an inferred resource of 0.8417 million tonnes at 0.26% WO_3, 0.20% MoS_2, 0.21% As, and 0.04% Bi (McCutcheon et al., 2013). The NI 43-101 mineral resource estimate for the North Zone includes an indicated resource of 12.4 million tonnes averaging 0.38% Sn, 0.86% Zn, and 64 ppm In, as well as an inferred resource of 2.8 million tonnes averaging 0.30% Sn, 1.13% Zn, and 70 ppm In (McCutcheon et al., 2013).

The area was staked in the 1950s as follow-up to a Cu and Pb stream sediment anomaly on the west flank of Mount Pleasant (Parrish, 1977). Since that time, surface trenching and stripping, diamond drilling, geophysical surveys, and soil geochemical surveys have been conducted; these combined activities led to the discovery of a significant Sn-W resource. A mine and a mill were constructed in 1980 to extract and process W, however falling W prices led to the mine's closure in 1985 (McCutcheon et al., 2010, 2013).

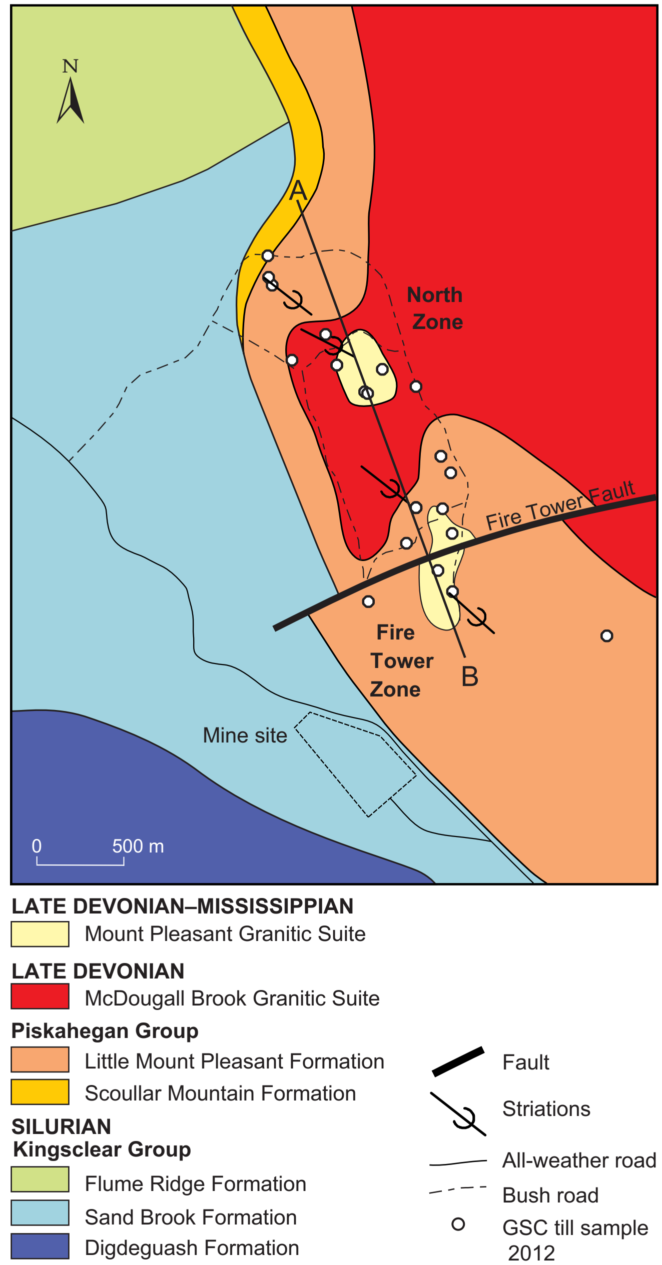

Figure 3. Local bedrock geology map of the Mount Pleasant Sn-W-Mo-Bi-In deposit area and location of GSC till samples (white dots) collected in 2012 up-ice (northwest), overlying, and down-ice (southeast) of the deposit (modified from McCutcheon et al., 1997, 2010).

Quaternary geology

Mount Pleasant is a striking topographic feature that rises approximately 220 m above the surrounding landscape, which is covered by a <1 m thick till veneer. The surrounding lower lying areas are covered by a 1 to

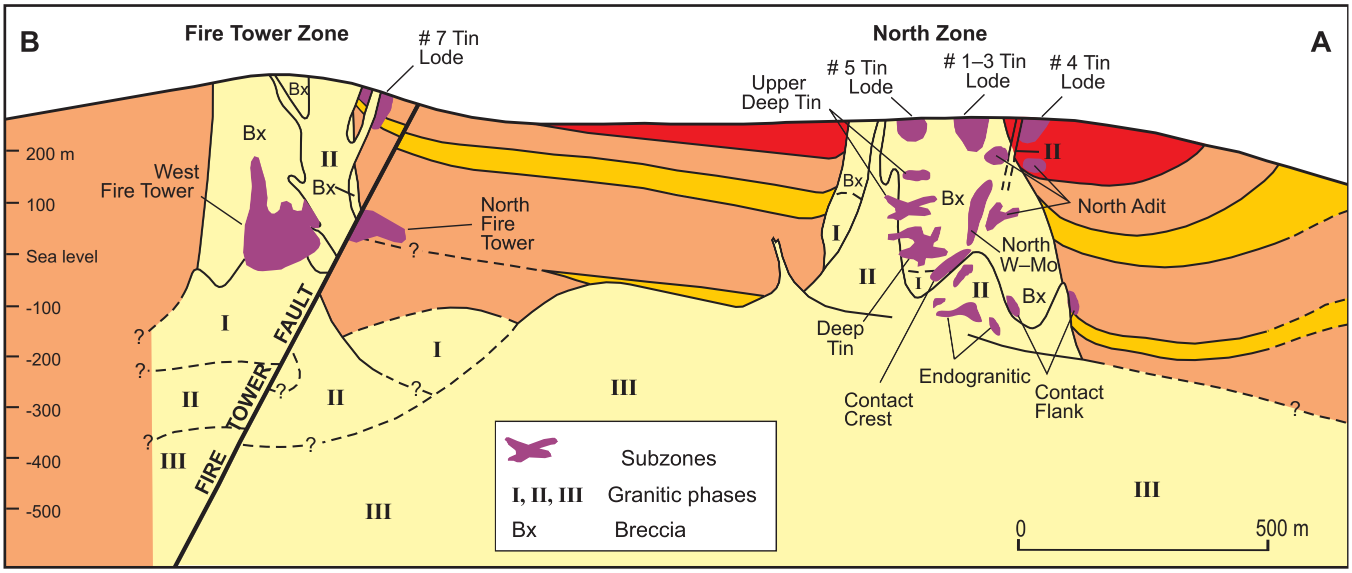

Figure 4. Cross-section A-B, shown in from Figure 2, through the North Zone and Fire Tower Zone at Mount Pleasant, showing the ore subzones (purple). Note subzones at the North Zone subcrop. Bedrock geology units are them same as those in Figure 2 (modified from McCutcheon et al., 1997, 2010).

5 m thick till blanket. The mountain has an elliptical shape with its long axis trending southeast. Till in the Mount Pleasant area was deposited by southeast- to south-southeast-flowing ice during the Caledonia Phase (Early to Middle Wisconsinan) (Allard, 2011; Stea et al., 2011). Allard (2011) mapped three coalescing southeasterly trending drumlins on Mount Pleasant. Szabo et al. (1975) reported evidence of ice flow towards the southeast (140–160°) based on striations measured on Mount Pleasant and from till fabrics measured on the Mount Pleasant mine property. Striations, measured on several outcrops on the mountain and in the surrounding low-lying areas as part of this study, also trend southeast.

Szabo et al. (1975) reported two types of till in the Mount Pleasant area: 1) a thin (<1.5 m thick) sandy silt till, which is restricted to the Mount Pleasant area, and 2) a thicker, coarse sandy till in the Mount Pleasant and broader area. Two types of till were observed while conducing till sampling as part of this study: an upper grey, sandy till and a lower reddish, silty till.

PREVIOUS TILL HEAVY MINERAL GEOCHEMICAL SURVEYS IN THE MOUNT PLEASANT AREA

Szabo et al. (1975), building on an earlier soil sampling survey by Riddell (1966), collected till samples around the Mount Pleasant deposit. The authors defined a glacial dispersal train extending more than 16 km southeast of the Mount Pleasant deposit using till geochemistry of the matrix fraction as well as the 0.5–2.0 mm (-10+35 mesh) heavy mineral concentrate (HMC) fraction (SG 2.92), which was ground to <0.177 mm and analyzed using a hot nitric acid digestion. They concluded that Sn (Fig. 5), As, Cu, Pb, and Zn in the coarser heavy mineral fraction best defined glacial dispersal from the deposit. In addition, they identified metal-rich till 1 km up-ice of the known North Zone mineralization. Also documented was the abundance of selected minerals, including fluorite, topaz, tourmaline, and pyrite (Table 2), that were present in grain mounts made of the 0.5–2.0 mm HMC and light fractions of several till samples collected along a northwest-southeast-trending transect across the deposit (Szabo, 1975; Szabo et al., 1975). Samples collected of till overlying the deposit contained a few grains of these four minerals, though samples collected up-ice (northwest) and down-ice (southeast) did not.

Szabo (1975) also sampled two eskers in the Mount Pleasant area: one located approximately 6 km down-ice from the Mount Pleasant deposit (1 sample) and the other approximately 6 km southwest of the Mount Pleasant deposit and directly down-ice (down-esker) from the Beech Hill and True Hill (Fig. 2) mineral occurrences (4 samples). These samples were found to contain only minor amounts of pyrite and tourmaline and did not contain any fluorite and topaz (Table 2).

METHODS

Till sampling

Twenty-three till samples were collected in the summer of 2012 from 22 sites up-ice, overlying, and up to 1.75 km down-ice (southeast) of the deposit (Figs. 6, 7) by GSC and NBDEM following GSC till sampling protocols (Spirito et al., 2011; McClenaghan et al., 2013). Sampling was focused around the North Zone and Fire

Table 1. Indicator minerals in the Mount Pleasant deposit (Petruk, 1972, 1973; Parrish, 1977; Kooiman et al., 1986; Sinclair et al., 2006) and those found in bedrock polished thin sections (PTS), bedrock heavy mineral concentrates (HMC), and till heavy mineral concentrates (HMC) from this study.

Mineral	Formula	Hardness	Specific Gravity	Presence Reported by Other Authors	Identified in Bedrock PTS in this Study	Identified in Bedrock HMC in this Study	Identified in Till HMC in this Study
Tin minerals							
cassiterite	SnO_2	6-7	6.8-7	Petruk (1972)	no	yes	yes
stannite	Cu_2FeSnS_4	3.5-4	4.3-4.5	Petruk (1972)	no	no	no
kësterite	$Cu_2(Zn,Fe)SnS_4$	4.5	4.54-4.59	Petruk (1972)	no	no	no
ferrokësterite	$Cu_2(Fe,Zn)SnS_4$	4.0	4.5	Parrish (1977)	no	no	no
stannoidite	$Cu_8Fe_3Sn_2S_{12}$	4	4.3	Petruk (1972)	no	no	no
mawsonite	$Cu_6Fe_2SnS_8$	3.5-4	4.7	Petruk (1972)	no	no	no
Tungsten minerals							
scheelite	$CaWO_4$	4-5	5.9-6.12	Parrish (1977)	no	no	yes
wolframite	$(Fe,Mn)WO_4$	4.5	7.1-7.5	Petruk (1972)	no	no	yes
Sulphide and arsenide minerals							
molybdenite	MoS_2	5.5	1	Petruk (1972)	no	no	yes
pyrite	FeS_2	5-5.02	6.5	Petruk (1972)	yes	yes	yes
marcasite	FeS_2	6.0-6.5	4.9	Petruk (1972)	no	no	no
sphalerite	$(Zn,Fe)S$	3.5-4	3.9-4.2	Petruk (1972)	yes	yes	no
pyrrhotite	$Fe_{(1-x)}S$ (x=0-0.17)	3.5-4	4.58-4.65	Petruk (1972)	no	no	no
arsenopyrite	$FeAsS$	5	6.1	Petruk (1972)	no	yes	yes
loellingite	$FeAs_2$	5.0	7.1-7.7	Petruk (1972)	no	no	yes
ferrimolybdite	$Fe_2(MoO_4)3{\bullet}8(H_2O)$	2.5-3	4-4.5	Parrish (1977)	no	no	no
scorodite	$Fe(AsO_4){\bullet}2(H_2O)$	3.5-4	3.1-3.3	Parrish (1977)	no	no	no
Bismuth minerals							
bismuthinite	Bi_2S_3	2	6.8-7.2	Petruk (1972)	no	no	no
native bismuth	Bi	2-2.5	9.7-9.8	Petruk (1972)	no	no	no
arsenobismite	$Bi_2(AsO_4)(OH)_3$	3	5.7	Parrish (1977)	no	no	no
zairite	$Bi(Fe,Al)_3[(OH)_6(PO_4)_2])$	4.5	4.4	no	no	no	yes
eulytite	$Bi_4(SiO_4)_3$	4.5	6.6	no	no	no	yes
Copper minerals							
chalcopyrite	$CuFeS_2$	3.5	4.1-4.3	Petruk (1972)	no	yes	no
covellite	CuS	1.5-2.0	4.6-4.76	Petruk (1972)	no	no	no
tennantite	$(Cu,Fe)_{12}As_4S_{13}$	3.5-4	4.6-4.7	Petruk (1972)	no	no	no
bornite	Cu_5FeS_4	3.0	4.9-5.3	Petruk (1972)	no	no	no
chalcocite	Cu_2S	2.5-3	5.5-5.8	Parrish (1977)	no	no	no
roquesite	$CuInS_2$	3.5-4	not reported	Petruk (1973)	no	no	no
digenite	Cu_9S_5	2.5-3	5.6	Parrish (1977)	no	no	no
famatinite	Cu_3SbS_4	3-4	4.6	Parrish (1977)	no	no	no
Lead minerals							
galena	PbS	2.5	7.2-7.6	Petruk (1972)	yes	yes	yes
wittichenite	Cu_3BiS_3	2.5	6.3-6.7	Petruk (1973)	no	no	no
galenobismutite	$PbBi_2S_4$	2.5-3	6.9-7.1	Petruk (1972)	no	no	no
aikinite	$PbCuBiS_3$	2-2.5	6.1-6.8	Petruk (1972)	no	no	no
cosalite	$Pb_2Bi_2S_5$	2.5-3	6.4-6.8	Petruk (1972)	no	no	no
krupkaite	$PbCuBi_3S_6$	4	7.0	Petruk (1972)	no	no	no
beudantite	$PbFe_3(AsO_4)(SO_4)(OH)_6$	4.0	4.1-4.3	no	no	no	yes
anglesite	$Pb(SO_4)$	2.5-3	6.3	no	no	no	yes
plumbogummite	$PbAl_3(PO_4)_2(OH)_5{\bullet}HO_2$	4-5	4-5	no	no	no	yes
Au and Ag minerals							
freibergite	$(Ag,Cu,Fe)_{12}(Sb,As)_4S_{13}$	3.5-4	4.85-5	Petruk (1973)	no	no	no
pyrargyrite	Ag_3SbS_3	2.5	5.9	Petruk (1973)	no	no	no
native silver	Ag	2.5-3	10-11	Petruk (1972)	no	no	no
gold	Au	2.5-3	16-19.3	Parrish (1977)	no	no	yes
Alteration minerals							
topaz	$Al_2SiO_4(F,OH)_2$	8	3.5-3.6	Petruk (1972)	yes	yes	yes
fluorite	CaF_2	4	3.01-3.25	Petruk (1972)	yes	yes	yes
tourmaline (black)	$NaAl_3Al_6(BO_3)_3(Si_6O_{18})(O,OH)_4$	7	3	Petruk (1972)	no	no	yes
columbite	$(Fe,Mn)(Nb,Ta)_2O_6$	6.0	5.3-7.3	Petruk (1972)	no	no	no

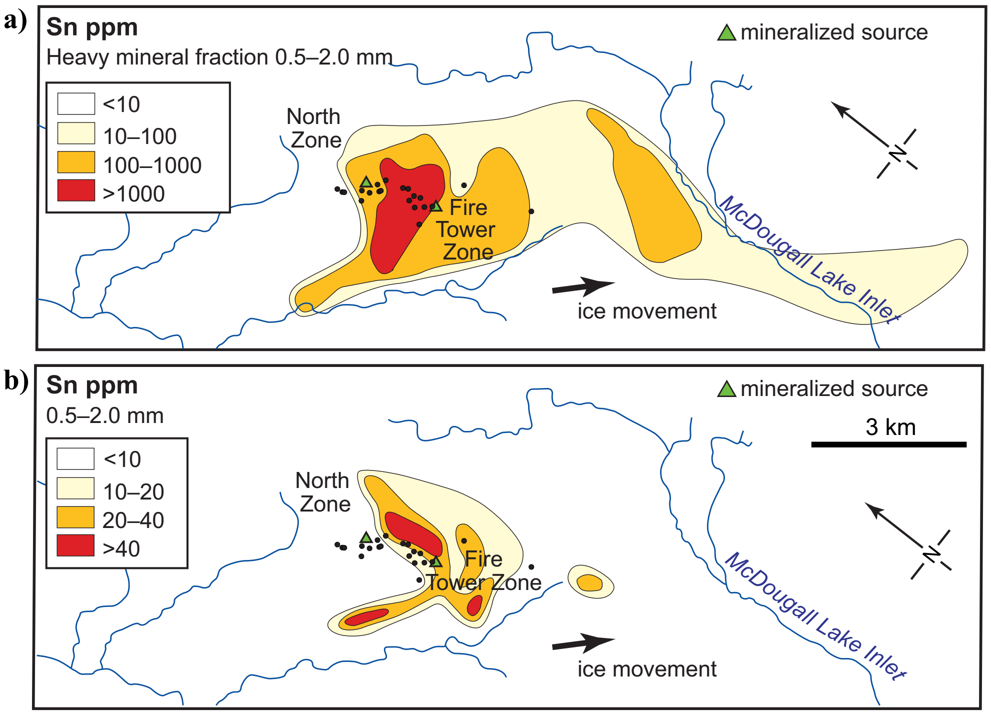

Figure 5. Distribution of Sn (ppm) in the **(a)** sand-size (0.5–2.0 mm) heavy mineral fraction (SG 2.95) and **(b)** sand-size (0.5–2.0 mm) fraction of surface till samples around the Mount Pleasant deposit reported by Szabo et al. (1975). Locations of GSC till samples collected in this study are shown as black dots.

Tower Zone. In addition, till sample 12-MPB-1024 was collected 12 km northwest of Mount Pleasant (Fig. 6) to characterize background (up-ice) till composition. Samples were collected at sites within the glacial dispersal train documented by Szabo et al. (1975) where till was sufficiently thick for sampling (>0.25 m) and at sites that were easily accessible by truck or foot traverse. Sample sites were either road cuts or hand-dug holes. Samples were collected at an average depth of 0.5 m and were of weakly (C-horizon) to moderately (B-horizon) oxidized till. Till sample locations, site descriptions, photographs, and sample depth information are reported in McClenaghan et al. (2015b). Information for all the till samples is reported in Appendix A.

At each site, three till samples were collected: (1) an 8 to 15 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 for in-field testing using a portable XRF (pXRF). To provide preliminary information about the W, Sn, Cu, Mo, Bi, and As content of the till, a 200 g sample was collected in a small disposable plastic bag and tested using a bench-top Innov-X 5000 XRF while moist and still in the bag. This geochemical information guided daily till sampling. One till site was sampled as a field duplicate to assess field variability: sample 12-MPB-1011 is a duplicate of 12-MPB-1010. The duplicate sample was collected from the same hole as the original sample.

Table 2. Abundance of fluorite, topaz, pyrite, and tourmaline in the 0.5–2.0 mm heavy mineral (specific gravity 2.92) fraction of seven till samples of unknown sample weight collected from a northwest-southeast transect across the Mount Pleasant deposit by Szabo et al. (1975).

Sample	Material	Location relative to the Fire Tower Zone	Fluorite	Topaz	Pyrite	Tourmaline
B-1	till	7 km up-up ice (NW)	1	0	3	1
622	till	overlying	1	2	3	6
121	till	overlying	2	1	1	3
123	till	overlying	4	2	4	5
N6	till	8 km down-ice (SE)	0	0	0	0
32	till	10 km down-ice (SE)	0	0	0	0
34	till	14 km down-ice (SE)	0	0	0	0
E1	esker sand	6 km SW of deposit	not reported	not reported	0	5
E3	esker sand	6 km SW of deposit	not reported	not reported	0	5
E5	esker sand	6 km SW of deposit	not reported	not reported	2	3
E7	esker sand	9 km S-SW of deposit	not reported	not reported	0	3
IC-2	esker sand	6 km down-ice (SE)	not reported	not reported	0	8

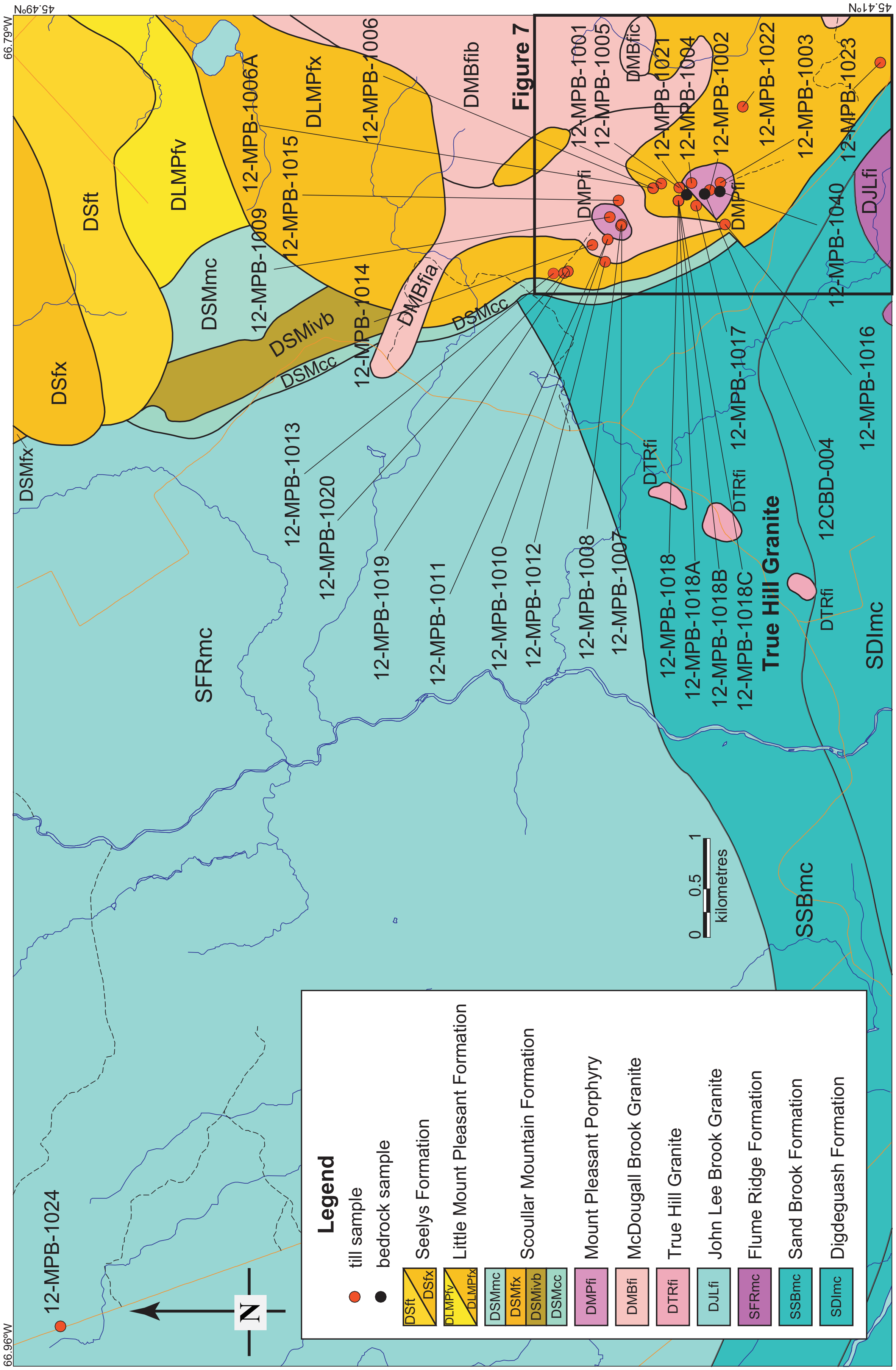

Figure 6. Location of till samples collected in the Mount Pleasant region during this study (bedrock geology from McLeod et al., 2005).

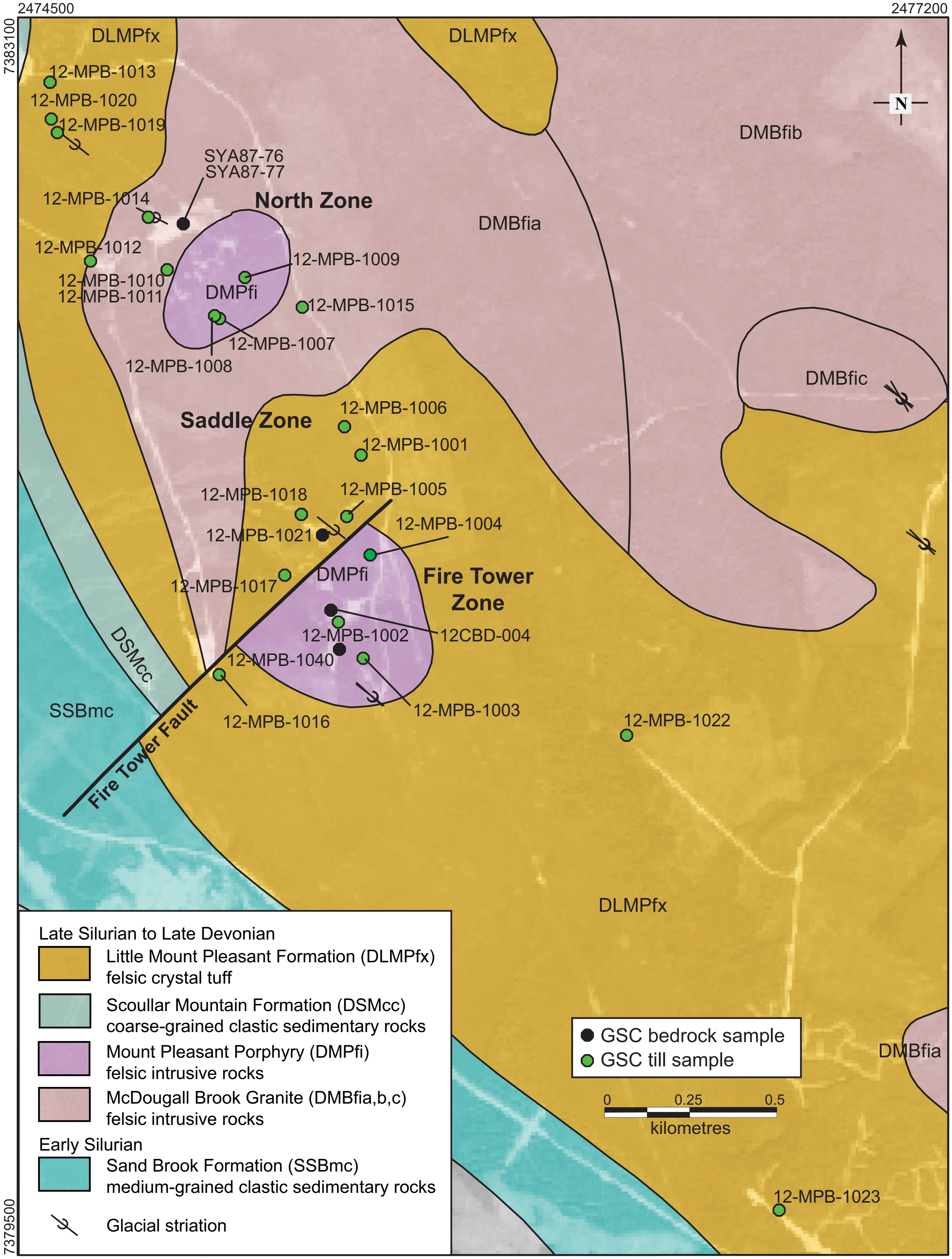

Figure 7. Location of GSC till (green dots) and bedrock (black dots) samples proximal to the Mount Pleasant deposit with an airphoto in the background (bedrock geology from McLeod et al., 2005).

Sample processing and indicator mineral picking

Heavy mineral samples were processed at Overburden Drilling Management Limited (ODM), Ottawa, to produce heavy mineral concentrates (HMC) for examination of indicator minerals. The unmodified datasheets reported by ODM are included in McClenaghan et al. (2014). A total of 23 till samples, plus two GSC in-house 'blanks', labeled 12-MPB-1001 and 12-MPB-1032, were processed. The blank samples were inserted into the till batch by GSC personnel prior to processing, to monitor carry-over contamination in the indicator mineral processing laboratory. These blanks, which are identified as 'Bathurst blank' in Appendix A, are weathered Silurian-Devonian granite (grus) of the South Nepisiguit River Plutonic Suite (Wilson, 2007) collected in the Miramichi Highlands, approximately 66 km west of Bathurst, New Brunswick (McClenaghan et al., 2012; Plouffe et al., 2013). This blank material is unconsolidated, has the appearance of moderately sorted monolithological sand, and other than rare pyrite or gold grains, does not contain any precious or base metal indicator minerals. Results for these two blank samples are reported along with the till samples.

The <2.0 mm fraction of till was processed to produce a non-ferromagnetic HMC for examination and counting of indicator minerals, as outlined in McClenaghan et al. (2014a). First, 10 to 15 kg of the <2.0 mm material was passed over a shaking table and the heavy table concentrate recovered and micro-panned to recover any gold, sulphides, tin, and tungsten minerals in the <0.25 mm fraction. The mineral grains in the panned concentrates were counted, their size and shape characteristics recorded, and then returned to the table concentrate. Table concentrates were then sieved at 0.25 mm. The 0.25 to 2.0 mm pre-concentrate was refined using heavy liquid separation in methylene iodide diluted to a SG of 3.2.

The <3.2 SG material was further refined using a heavy liquid with a SG of 3.0 and the <3.0 SG fraction was archived. The mid-density 3.0–3.2 SG fraction was washed and then sieved at 0.25, 0.5, and 1.0 mm; the 0.25–0.5 mm fraction was examined for indicator minerals.

The >3.2 SG fraction underwent ferromagnetic separation using a hand magnet. The ferromagnetic fraction was archived and the non-ferromagnetic heavy mineral fraction was sieved into three size fractions: 0.25–0.5 mm, 0.5–1.0 mm, and 1.0–2.0 mm. The 0.25–0.5 mm fraction was further subjected to paramagnetic separation using a Carpco® magnetic separator to produce <0.6 amp (strongly paramagnetic), 0.6 to 0.8 amp (moderately paramagnetic), 0.8 to 1.0 amp (weakly paramagnetic), and >1.0 amp (non-paramagnetic fractions) to assist in counting and picking of the indicator minerals in this fine-grained fraction. To facilitate optical mineral identification of the 0.25–0.5 mm fraction, it was cleaned with oxalic acid to remove oxidation stains (tarnish) from the grains and to restore natural colour, which is important primarily for sulphide minerals.

Mineral picking

The 0.25–0.5, 0.5–1.0, and 1.0–2.0 mm non-ferromagnetic heavy mineral (>3.2 SG) and mid-density (3.0–3.2 SG) fractions of the till samples were examined by trained personnel at ODM. Indicator minerals counted included cassiterite, scheelite, fluorite, topaz, gold, and sulphide minerals, as well as potential oxide and silicate indicators of massive sulphide deposits. The visual identification of a limited number of mineral grains was verified using a scanning electron microscope (SEM). All concentrates were systematically observed under shortwave ultraviolet light (UV) to determine the abundance of scheelite, which fluoresces a characteristic light whitish blue under shortwave UV light (McClenaghan et al., 2014a).

Data plotting

For the field duplicate samples, the data for the first sample of the duplicate pair was used in calculation of statistics and plotting distribution maps. The abundance of selected minerals was plotted using Mapinfo Professional® version 7.8 and represented by proportional dots. Thresholds of the intervals were determined using natural breaks in the data for all till samples, including the data for background sample 12-MPB-1024, which does not plot on the maps because it is located 12 km to the northwest.

RESULTS

Quality assurance/quality control

Blanks

Cross contamination was monitored using two Bathurst blank samples. Data for the blanks are reported in McClenaghan et al. (2014a). Sample 12-MPB-1000, inserted at the beginning of the batch, did not contain any indicator minerals. Sample 12-MPB-1032, inserted near the end of the batch amongst samples expected to be metal-rich, was found to contain one gold grain in the pan concentrate. This single grain is likely an occasional background gold grain, which the blank material has been reported to contain (McClenaghan et al., 2013; Plouffe et al., 2013).

Till field duplicate

Unnormalized and normalized indicator mineral abun-

Figure 8. Colour photographs of indicator mineral grains from the Mount Pleasant deposit area: **a)** prismatic brown cassiterite grains in the 0.25–0.5 mm fraction of till sample 12-MPB-1020; **b)** wolframite in the 0.25–0.5 mm fraction of till sample 12-MPB-1004; **c)** topaz in the 0.5–1.0 mm fraction of till sample 12-MPB-1004; and **d)** fluorite in the 0.5–1.0 mm fraction of till sample 12-MPB-1008. Grains were photographed by Michael Bainbridge Photography.

dances in the non-ferromagnetic 0.25–0.5 mm heavy (>3.2 SG) mineral fraction for the field duplicate pair are reported in Table 3 along with the routine sample data. Samples 12-MPB-1010 and -1011 are of similar weight and have similar indicator mineral counts, with the exception of wolframite. The normalized data are discussed here. Eight grains of wolframite were recovered from sample 12-MPB-1010 but none were recovered from sample 12-MPB-1011. Six grains of fluorite and one grain of loellingite were recovered from sample 12-MPB-1011 but none from sample 12-MPB-1010.

Cassiterite

Cassiterite (SnO_2) was identified in till HMC by its grain luster, typical yellow-brown colour, and prismatic crystal habit (Fig. 8a). Quartz was often attached to the cassiterite grains. The visual identification of some unusual cassiterite grains was confirmed using the SEM. Till samples were found to contain between 0 and 630 cassiterite grains in the 0.25–0.5 mm fraction and background abundance is zero grains (Table 3). Most grains were recovered from the 0.25–0.5 mm fraction (Appendix B, Map 1). A small number of 0.5–1.0 mm grains were recovered from ten till samples (Appendix B, Map 2) and three of these samples were also found to contain a few 1.0–2.0 mm grains (Appendix B, Map 3). No grains were recovered from the pan concentrates. Samples with the highest cassiterite abundances in all three size fractions were collected northwest (up-ice) or southeast (down-ice) proximal to the North Zone.

Wolframite

Wolframite ($(Fe,Mn)WO_4$) was identified in till HMC by its black colour and crystal habit (Fig. 8b). The identification of some unusual wolframite grains was confirmed using the SEM. Till samples contained between 0 and 35 grains of wolframite in the 0.25–0.5 mm fraction (Table 3), which is the size fraction from which the majority of the grains were recovered (Map 4, Appendix B). A few coarser grains were recovered from the 0.5–1.0 mm (Appendix B, Map 5) and the 1.0–2.0 mm fractions (Appendix B, Map 6). No grains were recovered from the pan concentrates of till samples. Samples with the highest wolframite abundances in all three size fractions are proximal to mineralization, either just west-northwest (up-ice) or southeast (down-ice) of the North Zone.

Topaz

Topaz ($Al_2SiO_4(F,OH)_2$) was identified in till HMC by its translucent white colour (Fig. 8c). It was recovered from all but two (12-MPB-1016, -1017) of the 23 till samples (Table 3). Samples contained between 0 and ~32,000 grains in the 0.25–0.5 mm fraction, with the highest number of topaz grains occurring in till overlying and southeast of the North Zone (Appendix B, Map 7). The 0.5–1.0 mm fraction of till contained 10s to 100s of grains (Appendix B, Map 8), and the 1.0–2.0 mm fraction contained a few grains in seven till samples (Appendix B, Map 9). Topaz was most abundant in till overlying the North and Fire Tower zones.

Pyrite

Most till samples do not contain pyrite (FeS_2) (Table 3). Five till samples were found to contain between 1 and 45 grains (Appendix B, Map 10), two of which were collected just northwest to west-northwest of the North Zone (samples 12-MPB-1012 and -1013).

Fluorite

Fluorite (CaF_2) abundance was determined for two density fractions: HMC (>3.2 SG) and the 0.25–2.0 mm mid-density (SG 3.0–3.2) fractions of till samples (Table 4). This is because the density range of fluorite is 3.01 to 3.25, which results in fluorite being recovered in both density fractions. Most fluorite grains, which were observed in the 3.0–3.2 SG fraction of six till samples (Tables 3, 4), are purple to clear (Fig. 8d). Counts ranged from 0 to 106 grains per 10 kg. The highest counts were from till samples collected just southeast of the North Zone (Appendix B, Map 11).

Tourmaline

Tourmaline [$NaAl_3Al_6(BO_3)_3(Si_6O_{18})(O,OH_4)$] abundance was determined for the HMC and the 0.25–2.0 mm mid-density (3.0–3.2 SG) fractions of all till sam-

Table 3. Indicator mineral abundance data for selected minerals in GSC till samples: **a)** counts normalized to a 10 kg mass of the <2 mm (table feed); **b)** raw count data (data from McClenaghan et al., 2014b).

a) Counts normalized to 10 kg mass of <2 mm fraction

Sample Number	Cassiterite			Wolframite			Topaz			Beudantite	Anglesite	Pyrite	Fluorite	Tourmaline	Scheelite	Arsenopyrite	Loellingite
	0.25-0.5 mm	0.5-1.0 mm	1.0-2.0 mm	0.25-0.5 mm	0.5-1.0 mm	1.0-2.0 mm	0.25-0.5 mm	0.5-1.0 mm	1.0-2.0 mm	0.25-0.5 mm	0.25-0.5 mm	0.25-0.5 mm	0.25-0.5 mm SG 3.0-3.2	0.25-0.5 mm SG 3.0-3.2	0.25-0.5 mm	0.25-0.5 mm	0.25-0.5 mm
12-MPB-1001	63	10	1	32	6	3	1190	40	0	0	3	1	0	32	0	0	11
12-MPB-1002	5	0	0	2	2	0	317	32	2	1587	2	0	0	5	0	0	0
12-MPB-1003	2	0	0	0	0	0	870	43	0	0	0	0	0	54	0	0	0
12-MPB-1004	12	0	0	32	13	0	31746	952	0	0	11905	0	12	32	0	0	0
12-MPB-1005	9	0	0	9	0	0	214	15	0	0	43	0	0	36	0	0	0
12-MPB-1006	53	10	0	35	19	2	4425	88	1	2	18	0	106	35	0	0	0
12-MPB-1007	8	1	0	2	0	0	500	42	4	0	1	0	4	83	0	0	0
12-MPB-1008	6	3	0	0	0	0	72	4	0	0	0	4	72	11	0	0	0
12-MPB-1009	10	0	0	0	0	0	1266	14	0	0	0	0	0	6	0	0	0
12-MPB-1010	37	3	0	8	2	0	2222	74	4	0	0	0	0	30	0	0	0
12-MPB-1011	45	4	0	0	0	0	1866	45	3	0	0	0	6	75	0	0	1
12-MPB-1012	89	36	0	14	1	0	268	15	0	0	0	45	0	45	0	0	0
12-MPB-1013	2	0	0	0	0	0	40	2	0	1	0	12	0	4	0	59	0
12-MPB-1014	2	0	0	0	0	0	1	0	0	0	0	0	13	35	1	0	0
12-MPB-1015	44	11	1	11	4	1	5556	222	12	0	0	0	0	20	0	0	0
12-MPB-1016	0	0	0	0	0	0	0	0	0	0	0	0	0	38	0	0	0
12-MPB-1017	0	0	0	0	0	0	0	0	0	0	0	0	0	43	1	0	0
12-MPB-1018	1	0	0	0	0	0	44	9	0	0	0	1	0	10	0	0	0
12-MPB-1019	7	3	0	0	0	0	14	2	0	1	1	0	0	68	0	0	0
12-MPB-1020	630	24	2	3	1	0	787	31	8	0	1181	0	0	31	0	0	0
12-MPB-1022	0	0	0	0	0	0	661	25	0	0	0	0	0	41	0	0	0
12-MPB-1023	0	0	0	0	0	0	561	37	0	0	0	0	0	37	0	0	1
12-MPB-1024	0	0	0	0	0	1	1	1	0	0	0	0	0	51	1	0	0

b) Raw counts not normalized

Sample Number	Cassiterite			Wolframite			Topaz			Beudantite	Anglesite	Pyrite	Fluorite	Tourmaline	Scheelite	Arsenopyrite	Loellingite	<2 mm mass (kg)
	0.25-0.5 mm	0.5-1.0 mm	1.0-2.0 mm	0.25-0.5 mm	0.5-1.0 mm	1.0-2.0 mm	0.25-0.5 mm	0.5-1.0 mm	1.0-2.0 mm	0.25-0.5 mm	0.25-0.5 mm	0.25-0.5 mm	0.25-0.5 mm SG 3.0-3.2	0.25-0.5 mm SG 3.0-3.2	0.25-0.5 mm	0.25-0.5 mm	0.25-0.5 mm	
12-MPB-1001	80	13	1	40	7	4	1500	50	0	0	4	1	0	40	0	0	14	12.6
12-MPB-1002	6	0	0	3	2	0	400	40	3	2000	3	0	0	6	0	0	0	12.6
12-MPB-1003	2	0	0	0	0	0	800	40	0	0	0	0	0	50	0	0	0	9.2
12-MPB-1004	15	0	0	40	16	0	40000	1200	0	0	15000	0	15	40	0	0	0	12.6
12-MPB-1005	13	0	0	13	0	0	300	21	0	0	60	0	0	50	0	0	0	14.0
12-MPB-1006	60	11	0	40	22	2	5000	100	1	2	20	0	120	40	0	0	0	11.3
12-MPB-1007	10	1	0	2	0	0	600	50	5	0	1	0	5	100	0	0	0	12.0
12-MPB-1008	8	4	0	0	0	0	100	6	0	0	0	5	100	15	0	0	0	13.8
12-MPB-1009	8	0	0	0	0	0	1000	11	0	0	0	0	0	5	0	0	0	7.9
12-MPB-1010	50	4	0	11	3	0	3000	100	6	0	0	0	0	40	0	0	0	13.5
12-MPB-1011	60	5	0	0	0	0	2500	60	4	0	0	0	8	100	0	0	1	13.4
12-MPB-1012	100	40	0	16	1	0	300	17	0	0	0	50	0	50	0	0	0	11.2
12-MPB-1013	2	0	0	0	0	0	50	2	0	1	0	15	0	5	0	74	0	12.6
12-MPB-1014	3	0	0	0	0	0	1	0	0	0	0	0	19	50	1	0	0	14.1
12-MPB-1015	40	10	1	10	4	1	5000	200	11	0	0	0	0	18	0	0	0	9.0
12-MPB-1016	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	10.6
12-MPB-1017	0	0	0	0	0	0	0	0	0	0	0	0	0	50	1	0	0	11.7
12-MPB-1018	2	0	0	0	0	0	60	12	0	0	0	2	0	13	0	0	0	13.5
12-MPB-1019	8	4	0	0	0	0	16	2	0	1	1	0	0	80	0	0	0	11.7
12-MPB-1020	800	30	2	4	1	0	1000	40	10	0	1500	0	0	40	0	0	0	12.7
12-MPB-1022	0	0	0	0	0	0	800	30	0	0	0	0	0	50	0	0	0	12.1
12-MPB-1023	0	0	0	0	0	0	600	40	0	0	0	0	0	40	0	0	1	10.7
12-MPB-1024	0	0	0	0	0	1	1	1	0	0	0	0	0	60	1	0	0	11.7

Table 4. Fluorite abundance data for the 0.25–0.5 mm fraction of GSC till samples (normalized to a 10 kg mass of the <2 mm table feed) with a specific gravity (SG) of 3.0 to 3.2 and with a specific gravity of >3.2.

Sample Number	Fluorite 0.25–0.5 mm	
	SG 3.0–3.2	SG >3.2
12-MPB-1001	0	0
12-MPB-1002	0	0
12-MPB-1003	0	0
12-MPB-1004	12	0
12-MPB-1005	0	0
12-MPB-1006	106	0
12-MPB-1007	4	1
12-MPB-1008	72	9
12-MPB-1009	0	0
12-MPB-1010	0	0
12-MPB-1011	6	1
12-MPB-1012	0	0
12-MPB-1013	0	1
12-MPB-1014	13	0
12-MPB-1015	0	0
12-MPB-1016	0	0
12-MPB-1017	0	0
12-MPB-1018	0	0
12-MPB-1019	0	0
12-MPB-1020	0	0
12-MPB-1022	0	0
12-MPB-1023	0	0
12-MPB-1024	0	0

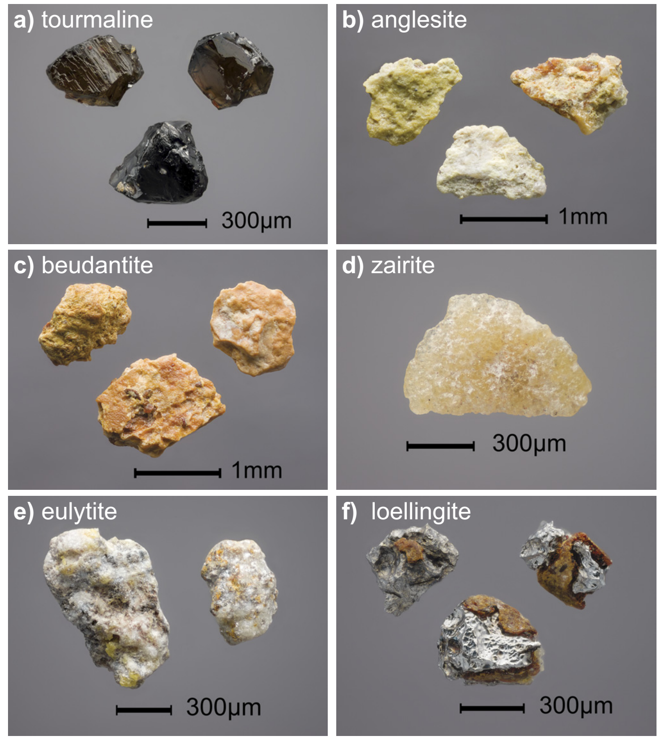

Figure 9. Colour photographs of indicator mineral grains from the Mount Pleasant deposit area: **a)** tourmaline in the 0.25–0.5 mm fraction of sample 12-MPB-1007; **b)** anglesite in the 0.25–0.5 mm fraction of till sample 12-MPB-1004; **c)** beudantite in the 0.25–0.5 mm fraction of till sample 12-MPB-1002; **d)** zairite in the 0.25–0.5 mm fraction of till sample 12-MPB-1019; **e)** eulytite in the 0.25–0.5 mm fraction of till sample 12-MPB-1002; and **f)** loellingite in the 0.25–0.5 mm fraction of till sample 12-MPB-1001. Grains were photographed by Michael Bainbridge Photography.

ples, as the density range of tourmaline (3.1–3.2 SG) also spans both density fractions. Only trace amounts were reported in the >3.2 SG fraction. However, the 3.0–3.2 SG fraction the till samples contained between 4 and 83 grains (Table 3; Appendix B, Map 12). Tourmaline grains in the till samples in this study are brown to black (Fig. 9a), stubby, columnar crystals that sometimes show striations. No SEM checks were required to identify the tourmaline grains.

Arsenopyrite

One till sample, 12-MPB-1013, collected 500 m northwest of the North Zone, was found to contain arsenopyrite (FeAsS). This till sample contained 59 grains in the 0.25–0.5 mm HMC fraction.

Secondary minerals

Anglesite ($Pb(SO_4)$) is a secondary Pb-sulphate mineral that is a product of the weathering of galena. Grains (Fig. 9b) were recovered from the 0.25–0.5 mm HMC fraction of eight till samples (Table 3). Approximately 12,000 gains were recovered from till sample 12-MPB-1004, collected over the Fire Tower Zone, and ~1200 grains were recovered from till sample 12-MPB-1020, collected 500 m northwest of the North Zone (Appendix B, Map 13). The other six samples contained only 1 to 3 grains.

Beudanitite [$PbFe_3(AsO_4)(SO_4)(OH)_6$] is a secondary sulphate mineral that is found in the oxidized zones of polymetallic deposits. It was identified in till HMC by SEM checks on grains that visually resembled goethite (Fig. 9c). It was identified in four till samples (Table 3): 1587 grains in heavily oxidized till sample 12-MPB-1002 collected overlying the Fire Tower Zone, 2 grains in sample 12-MPB-1006, and 1 grain in each of samples 12-MPB-1013 and 12-MPB-1019 (Map 14, Appendix B).

One grain of plumbogummite [$PbAl_3(PO_4)2(OH)_5 H_2O)$], a Pb-phosphate mineral, was identified in the 0.25–0.5 mm fraction of till sample 12-MPB-1022 during a SEM check of a grain that looked like goethite or jarosite. It is a secondary mineral that can be found in the oxidized zones of Pb-bearing deposits.

One zairite ($Bi(Fe,Al)_3[(OH)_6(PO_4)_2]$) grain (Fig. 9d) was recovered from the 0.25–0.5 mm fraction of till sample 12-MPB-1019, collected 500 m northwest of the North Zone. It was identified while using the SEM to check the identity of a grain that looked like goethite. It is a secondary phosphate mineral that can be found in wolframite-bearing granite pegmatite (Webmineral, 2015).

Gold

Gold grains, when present, were recovered from the pan concentrates of till samples. Ten samples were found to have 1 to 2 visible gold grains (25–175 µm). Most grains have been classified as 'reshaped' (McClenaghan et al. 2014a). The low abundance and shape (e.g. DiLabio, 1990) of the gold grains recovered from the till samples indicate that all the gold grains are likely background grains and are unrelated to the Mount Pleasant deposit.

Other minerals

Two eulytite ($Bi_4(SiO_4)_3$) grains (Fig. 9e) were recovered from the 0.25–0.5 mm fraction of till sample 12-MPB-1002, during SEM checks of grains that looked like zoisite. Three till samples contained loellingite ($FeAs_2$): samples 12-MPB-1001 (14 grains), 12-MPB-1011 (1 grain), and 12-MPB-1023 (1 grain). It was identified in the 0.25–0.5 mm fraction of till HMC by its bright silvery white metallic colour (Fig. 9f). One 0.25–0.5 mm molybdenite (MoS_2) grain was recovered from till sample 12-MPB-1004. One 0.25–0.5 mm grain of galena (PbS) was recovered from till sample 12-MPB-1013.

DISCUSSION

Glacial dispersal of indicator minerals

Szabo et al. (1975) documented glacial dispersal from the Mount Pleasant deposit up to 16 km down-ice (southeast), based on the Sn, Cu, Pb, and Zn content of the till matrix. The authors' highest metal values in till were found within the first 3 km of the dispersal train. In our study, till samples were collected a maximum of 2 km down ice (southeast), which is well within the most metal-rich part of Szabo et al.'s dispersal train, to document the species and abundance of indicator minerals down-ice of the deposit. Szabo et al. (1975) also documented the presence of fluorite, topaz, pyrite, and tourmaline in till samples overlying the deposit (Table 2).

Indicator minerals recovered from till samples at the Mount Pleasant deposit in the current study include the main ore minerals cassiterite (Sn), wolframite (W), and molybdenite (Mo), as well as galena, arsenopyrite, loellingite, fluorite, and topaz. Tables 2 and 3 combined with the maps included in Appendix B show that indicator mineral contents in till samples are lowest in background sample 12-MPB-1024 and highest in samples overlying the North Zone and immediately southeast and, to a lesser extent, over the Fire Tower Zone. Till samples 12-MPB-1019, and -1020, collected 500 m northwest of the North Zone, also contained high counts of indicator minerals, suggesting that additional subcropping mineralization is likely present to the northwest of the North Zone.

Secondary indicator minerals recovered from till include Pb-sulphate minerals beudantite and anglesite, and the Pb-phosphate mineral plumbogummite. These minerals formed from the oxidation and weathering of the galena. It is unclear whether they formed during preglacial weathering of the mineralization or postglacial weathering of the thin (<0.25 m) veneer of till that covers the mineralization. One secondary phosphate mineral, zairite, was recovered from till sample 12-MPB-1019, collected 500 m northwest of the North Zone.

Indicator mineral size

All indicator mineral species recovered from till were most abundant in 0.25–0.5 mm fraction of the sample. Coarser (0.5–2.0 mm) grains of cassiterite, wolframite, and topaz were also recovered from till samples collected over or just down-ice (<1 km southeast) of the North Zone. Their presence in till is a strong indicator of proximity to mineralization.

The presence of tourmaline has been documented for the Mount Pleasant deposit as well as the nearby True Hill and Beech Hill (Fig. 2) intrusion-hosted polymetallic occurrences (Hosking, 1963; Ruitenberg, 1967; Dagger, 1972; Petruk, 1973; Szabo et al., 1975; Parrish, 1977; Ruitenberg and McCutcheon, 1985; Kooiman, et al., 1986; Lentz and MacAllister, 1990; Lentz, 1994; NBDEM, 2015). Tourmaline is present in the Mount Pleasant deposit, although in minor amounts, and is mostly associated with parts of the deposit containing cassiterite (Petruk, 1973). The distribution of tourmaline minerals in till samples in this study seems to suggest it is associated with both the Fire Tower and North zones. Tourmaline is a common non-metallic alteration mineral associated with Mount Pleasant and other porphyry deposits of this type, especially the well known Bolivian deposits (Sillitoe et al., 1975). Regardless, tourmaline's hardness (7–7.5) and association make it a useful indicator mineral for intrusion-hosted Sn deposits similar to Mount Pleasant.

Comparison to indicator minerals in mineralized bedrock samples

The indicator minerals that were recovered from the till around the Mount Pleasant deposit are similar to those recovered from mineralized rocks of the deposit. Indicator minerals seen in bedrock samples include cassiterite, molybdenite, sphalerite, chalcopyrite, galena, arsenopyrite, pyrite, topaz, and fluorite (McClenaghan et al., 2014b). All the bedrock samples that were examined were fresh and unoxidized, thus none of the secondary sulphate and phosphate minerals recovered from till were recovered from the bedrock samples. Significantly fewer indicator minerals (1s to 10s of grains) were recovered from the pan concentrate fractions of till samples than from the mineralized bedrock samples (100s to 10,000s of grains). Wolframite was recovered from till samples in this study, though none were recovered from the bedrock samples examined.

Comparison to indicator minerals of the Sisson W-Mo deposit

Indicator minerals for the Sisson W-Mo deposit, the other intrusion-hosted polymetallic deposit that was studied as part of the TGI-4 program, are similar to those recovered from till at the Mount Pleasant deposit, which includes wolframite, molybdenite, galena, arsenopyrite, and pyrite. Unlike the Mount Pleasant deposit, the Sisson deposit is a W-Mo deposit and thus its primary indicator mineral in till is scheelite. In contrast, the primary W mineral in the Mount Pleasant deposit and in till around the deposit is wolframite.

The minerals recovered from the Sisson deposit also differ in that no secondary sulphate or phosphate minerals were recovered from the till samples. This absence likely reflects the fact that the Sisson deposit is covered by a thicker till blanket (2–8 m) than the Mount Pleasant deposit and does not outcrop. Thus the Sisson deposit has been protected from surface oxidation and weathering since deglaciation, preventing the oxidation of galena and the formation of secondary minerals.

CONCLUSIONS

This is the first detailed indicator mineral study around a major Sn deposit in glaciated terrain. Indicator minerals in till at the Mount Pleasant deposit include the main ore minerals cassiterite, wolframite, and molybdenite, as well as topaz, galena, arsenopyrite, and loellingite in the 0.25–0.5 mm >3.2 SG fraction of till, and fluorite and tourmaline in the 0.25–2.0 mm 3.0–3.2 SG fraction. Useful indicator minerals also include secondary minerals beudantite, anglesite, and rare plumbogummite, all of which formed from the pre- or postglacial oxidation of galena. Collectively, the indicator minerals in till that have been identified in this study reflect the presence of Sn-W mineralization as well as the polymetallic nature of the deposit.

The presence of coarse (0.5–2.0 mm) indicator minerals in till around the Mount Pleasant deposit is influenced by proximity (<1 km) to the mineralized source. The group of indicator minerals recovered from till around the Mount Pleasant deposit is similar to the suite of indicator minerals recovered from mineralized rocks from the deposit, including cassiterite, molybdenite, sphalerite, chalcopyrite, galena, arsenopyrite, pyrite, topaz, and fluorite. Wolframite was recovered from till samples at the Mount Pleasant deposit, but not the five bedrock samples that were examined in this study.

ACKNOWLEDGEMENTS

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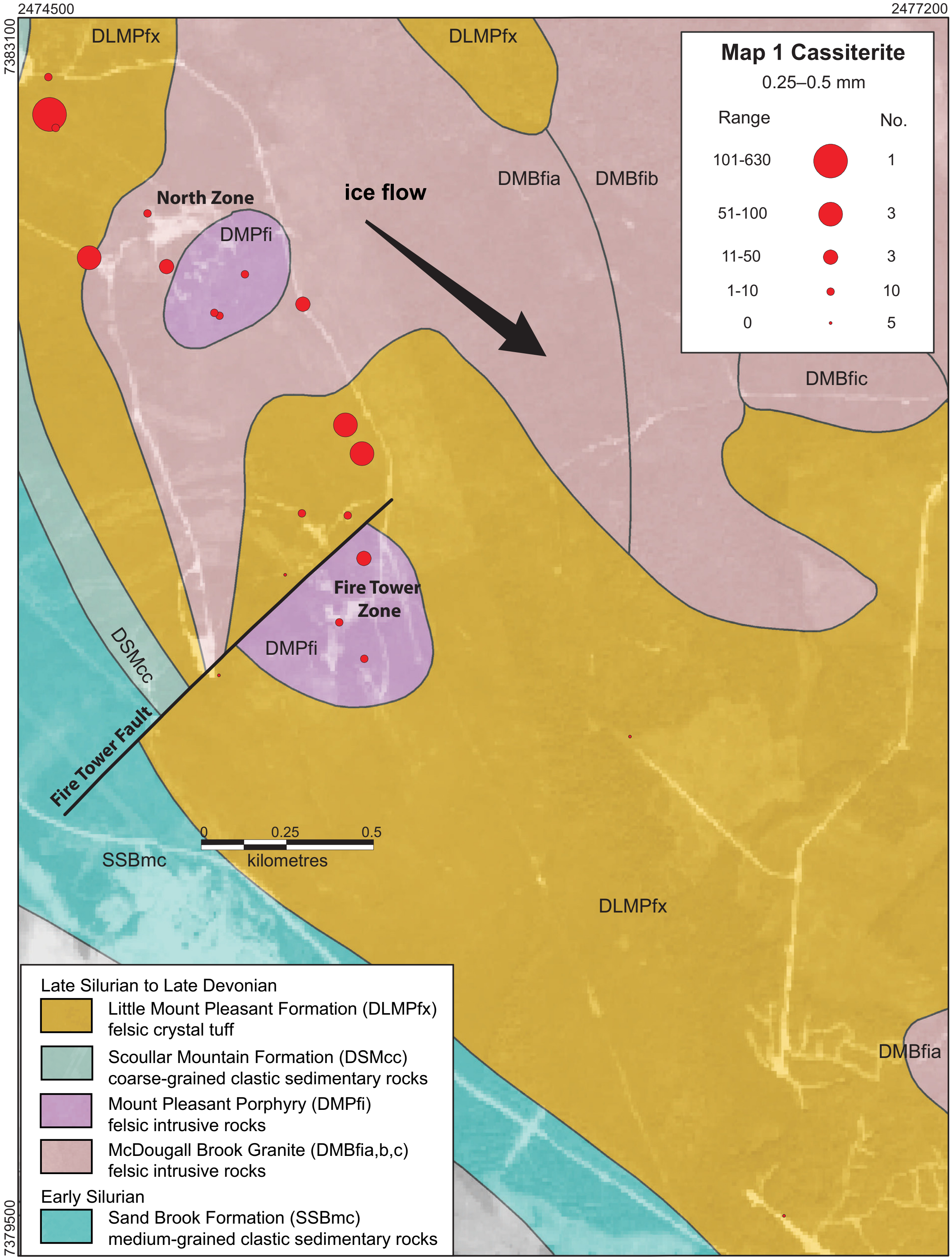
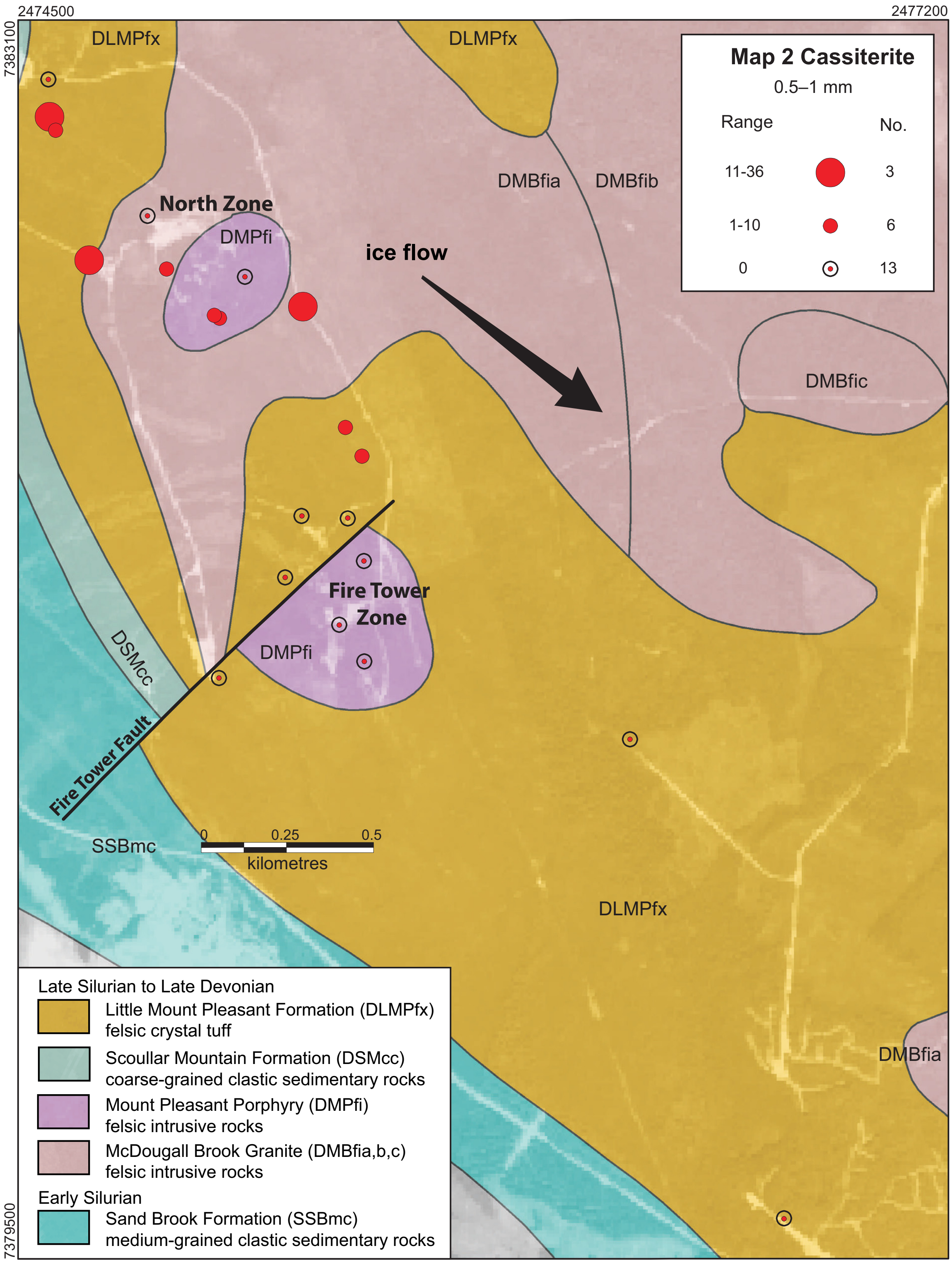
APPENDIX B. Proportional dot maps showing indicator mineral abundances in varying sizes of the non-ferromagnetic >3.2 SG fraction of till normalized to a 10 kg weight of <2 mm (table feed). Bedrock geology modified from McLeod et al. (2005).



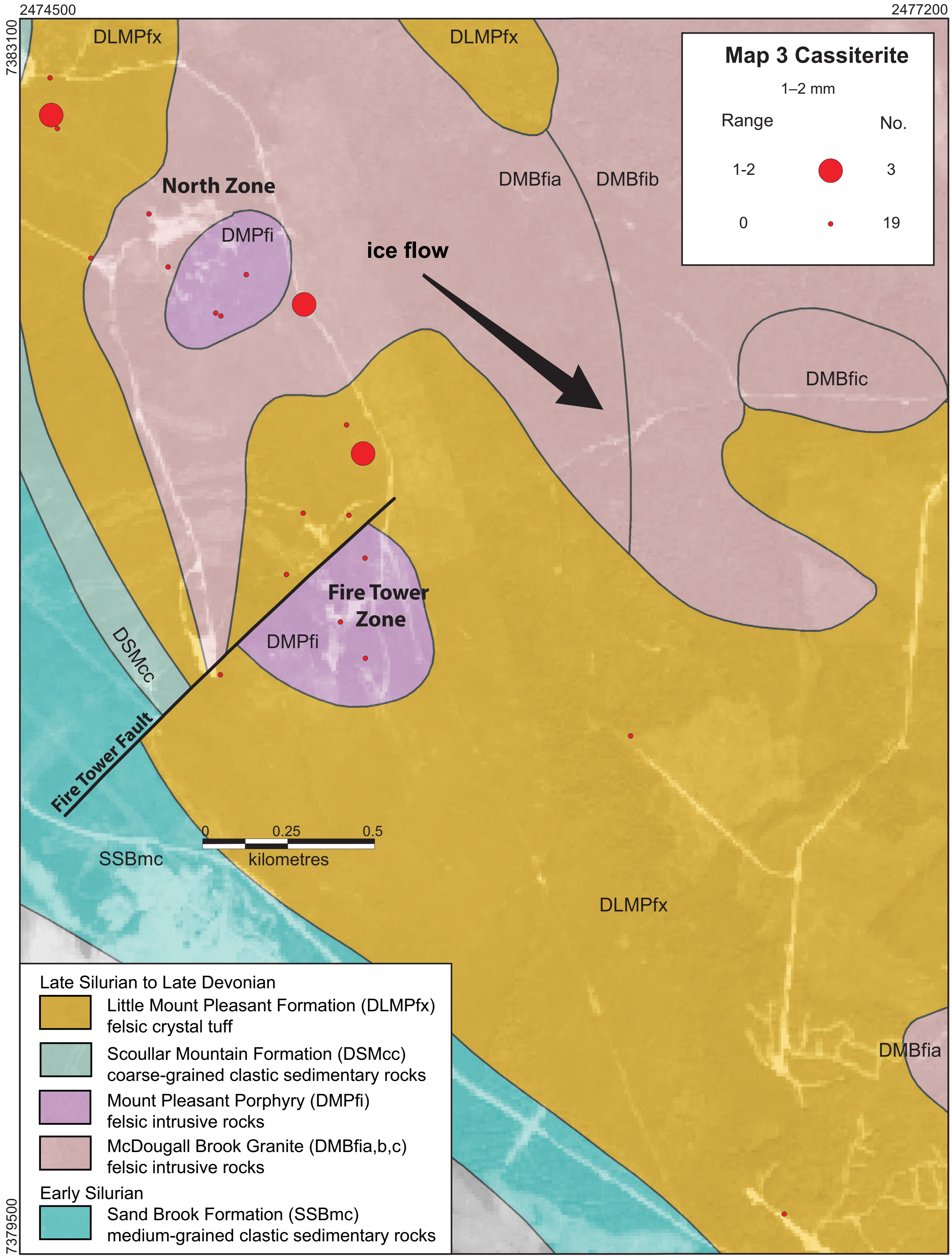
Map 1. Proportional dot map showing cassiterite abundance in the non-ferromagnetic, >3.2 SG, 0.25–0.5 mm fraction of till samples normalized to a 10 kg weight of <2 mm (table feed). Bedrock geology modified from McLeod et al. (2005).

APPENDIX B continued.



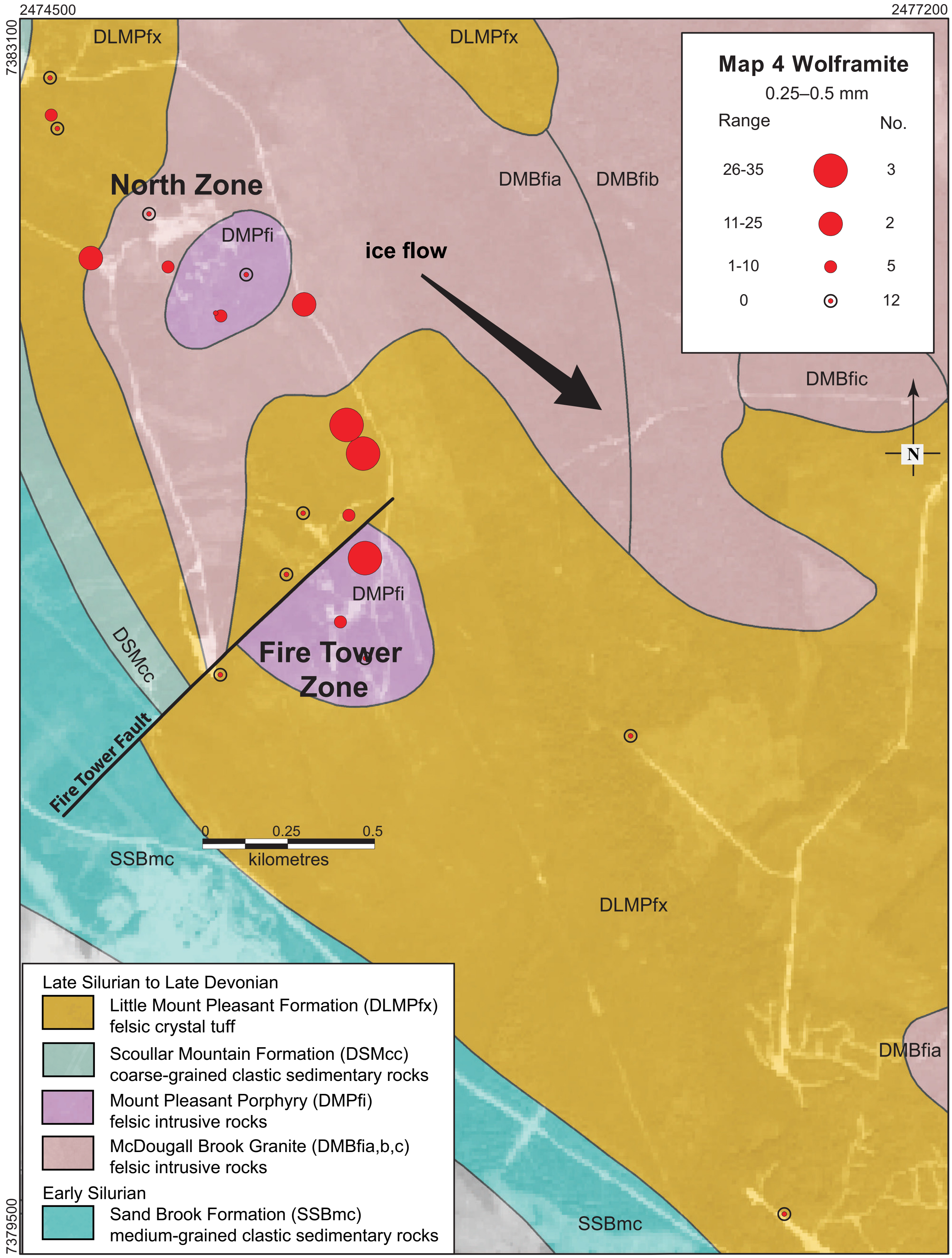
Map 2. Proportional dot map showing cassiterite abundance in the non-ferromagnetic, >3.2 SG, 0.5–1.0 mm fraction of till samples normalized to a 10 kg weight of <2 mm (table feed). Bedrock geology modified from McLeod et al. (2005).

APPENDIX B continued.



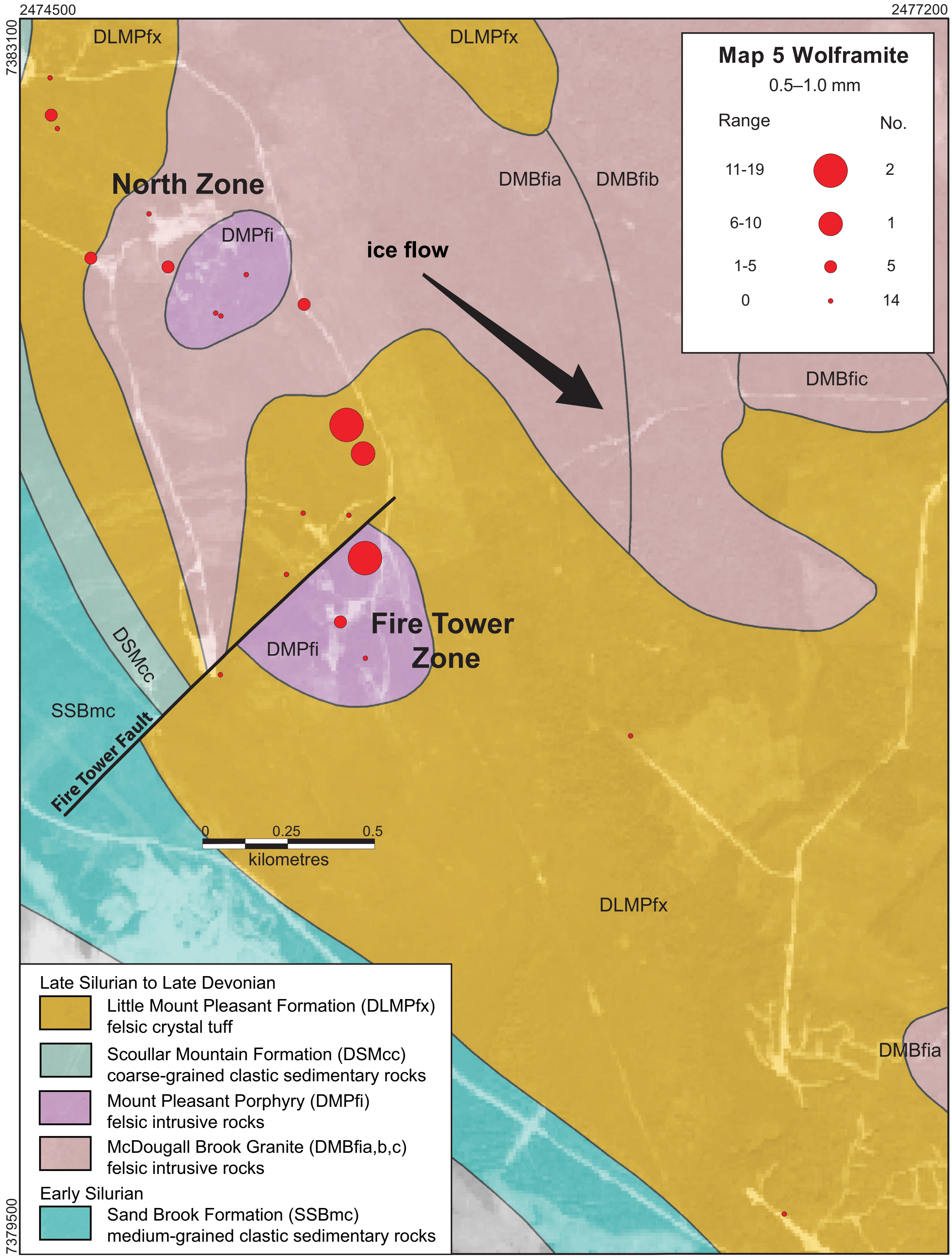
Map 3. Proportional dot map showing cassiterite abundance in the non-ferromagnetic, >3.2 SG, 1.0–2.0 mm fraction of till samples normalized to a 10 kg weight of <2 mm (table feed). Bedrock geology modified from McLeod et al. (2005).

APPENDIX B continued.



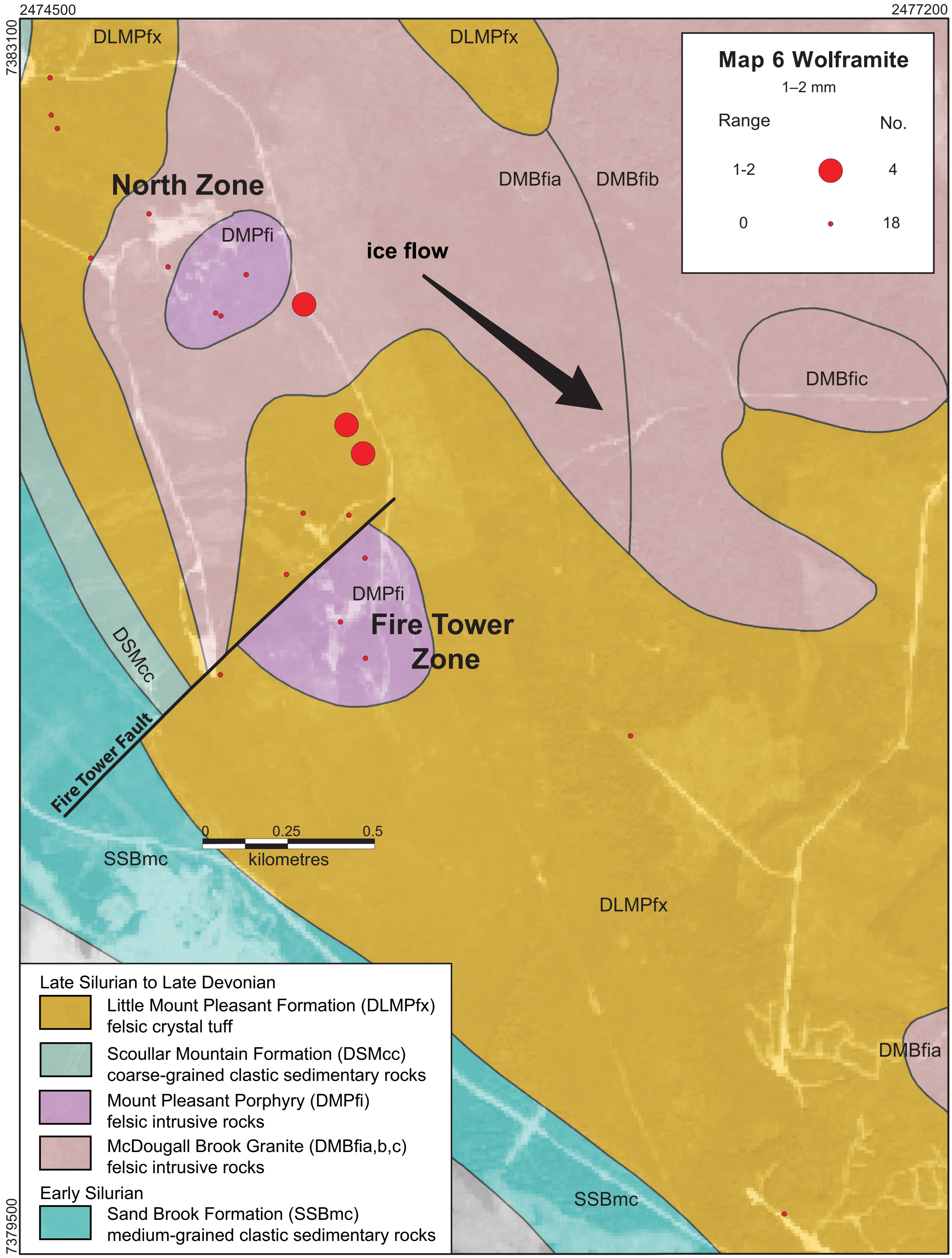
Map 4. Proportional dot map showing wolframite abundance in the non-ferromagnetic, >3.2 SG, 0.25–0.5 mm fraction of till samples normalized to a 10 kg weight of <2 mm (table feed). Bedrock geology modified from McLeod et al. (2005).

APPENDIX B continued.



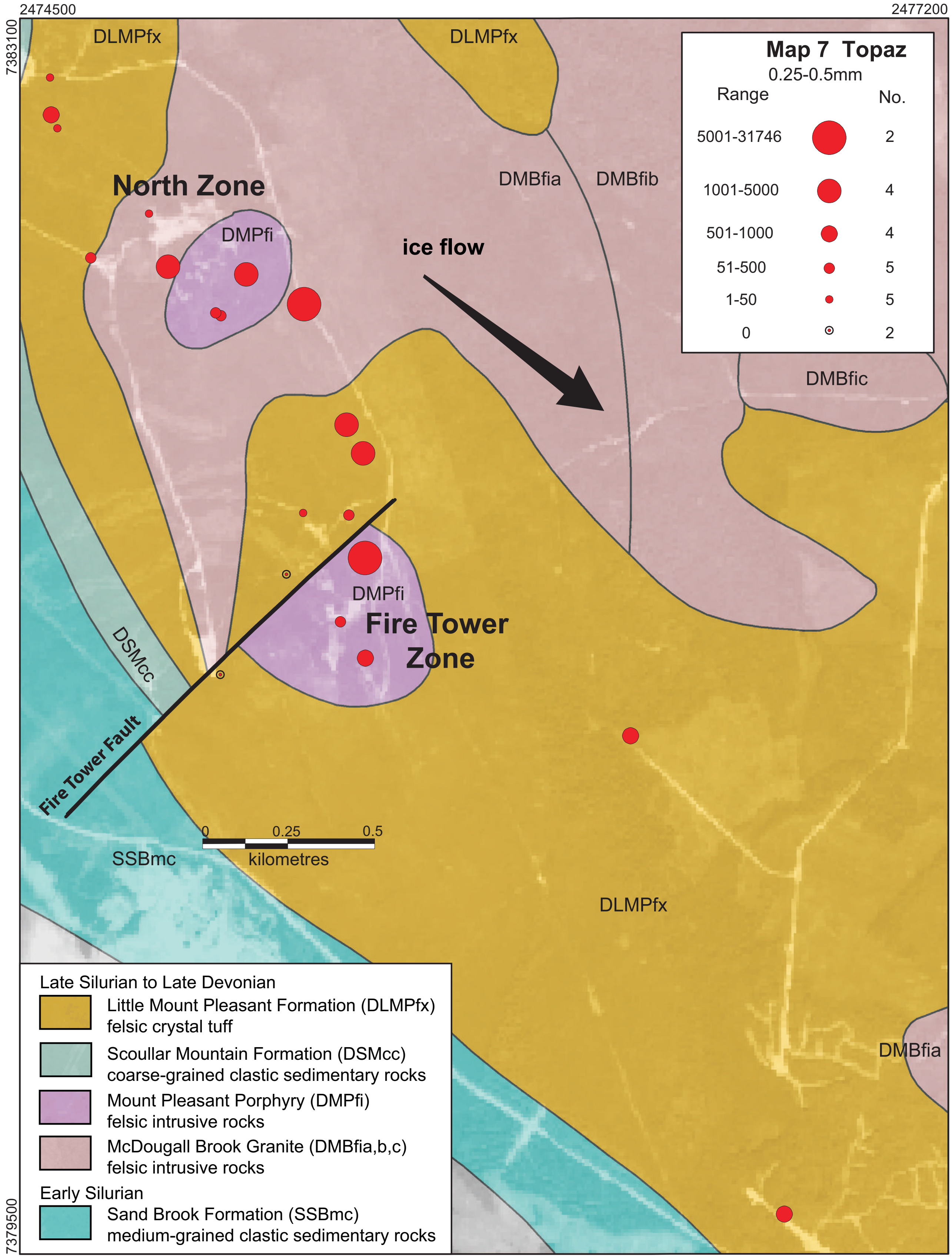
Map 5. Proportional dot map showing wolframite abundance in the non-ferromagnetic, >3.2 SG, 0.5–1.0 mm fraction of till samples normalized to a 10 kg weight of <2 mm (table feed). Bedrock geology modified from McLeod et al. (2005).

APPENDIX B continued.



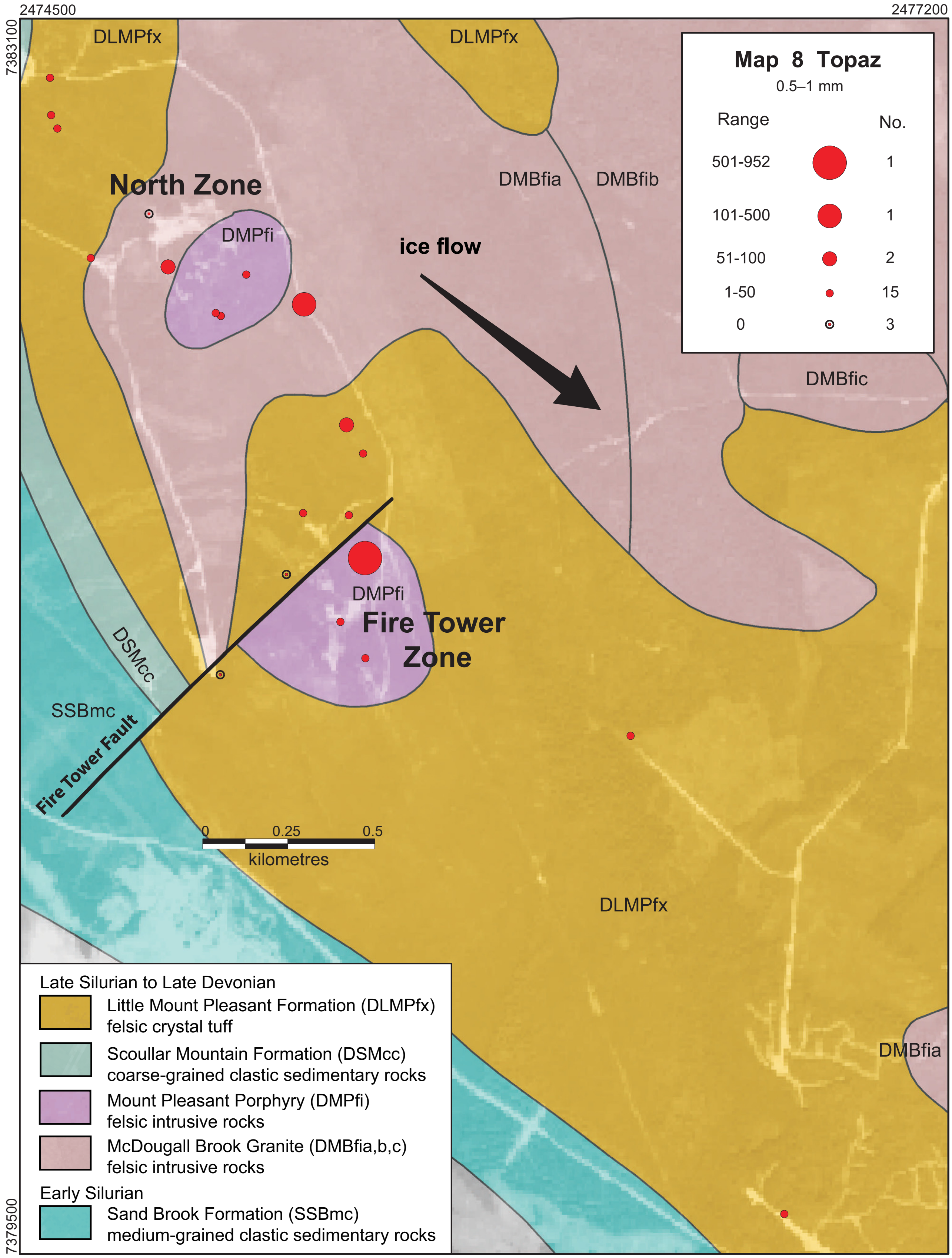
Map 6. Proportional dot map showing wolframite abundance in the non-ferromagnetic, >3.2 SG, 1.0–2.0 mm fraction of till samples normalized to a 10 kg weight of <2 mm (table feed). Bedrock geology modified from McLeod et al. (2005).

APPENDIX B continued.



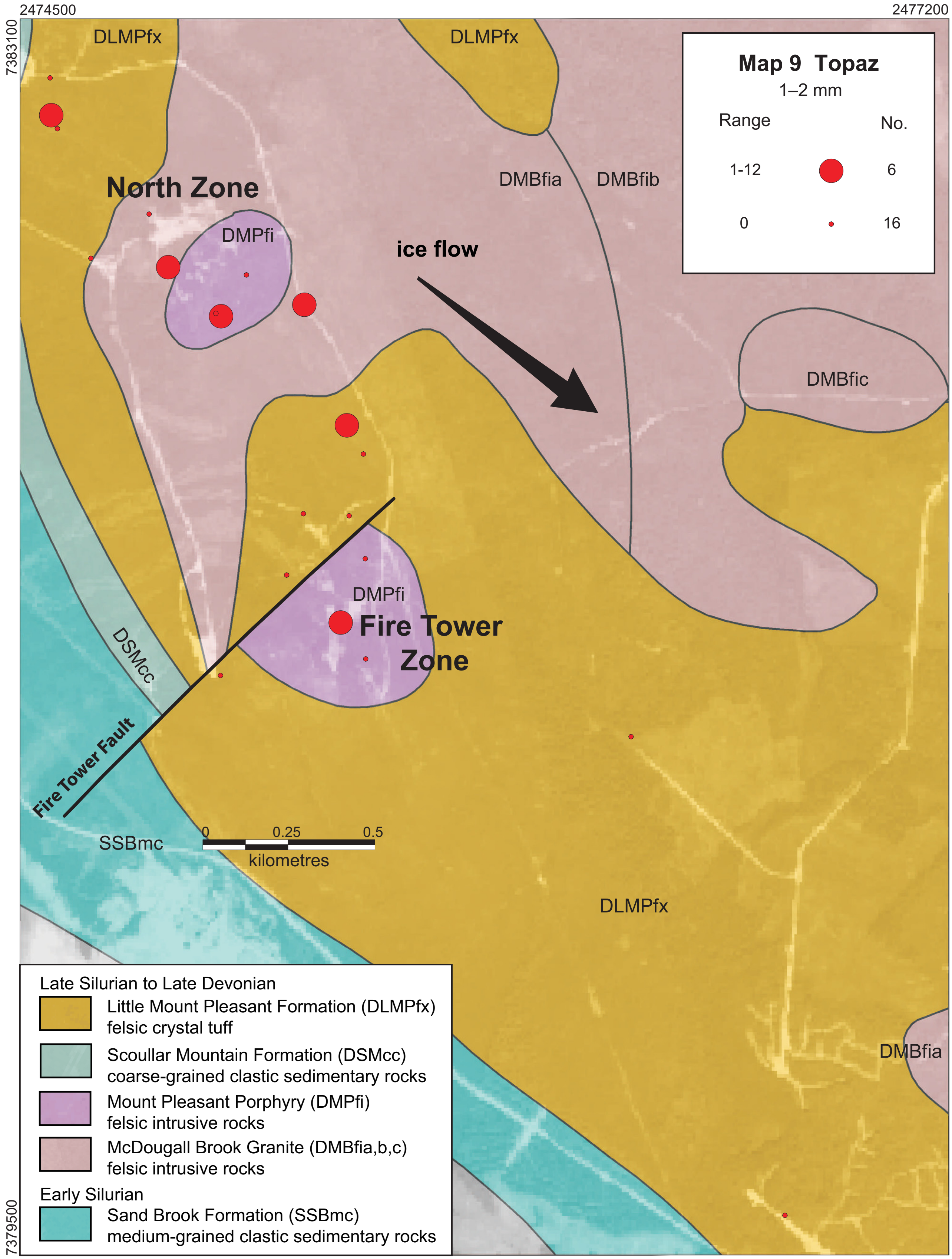
Map 7. Proportional dot map showing topaz abundance in the non-ferromagnetic, >3.2 SG, 0.25–0.5 mm fraction of till samples normalized to a 10 kg weight of <2 mm (table feed). Bedrock geology modified from McLeod et al. (2005).

APPENDIX B continued.



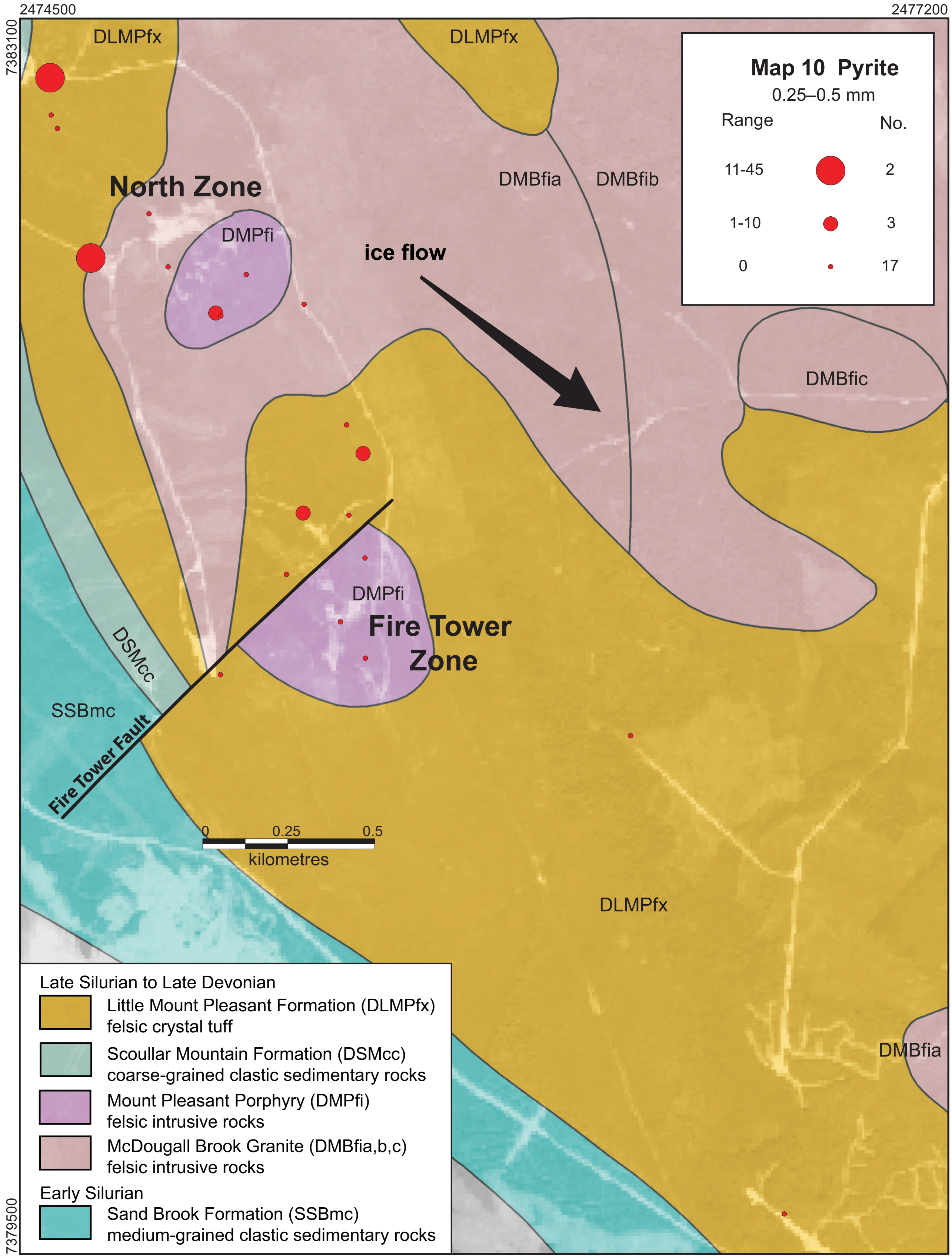
Map 8. Proportional dot map showing topaz abundance in the non-ferromagnetic, >3.2 SG, 0.5–1.0 mm fraction of till samples normalized to a 10 kg weight of <2 mm (table feed). Bedrock geology modified from McLeod et al. (2005).

APPENDIX B continued.



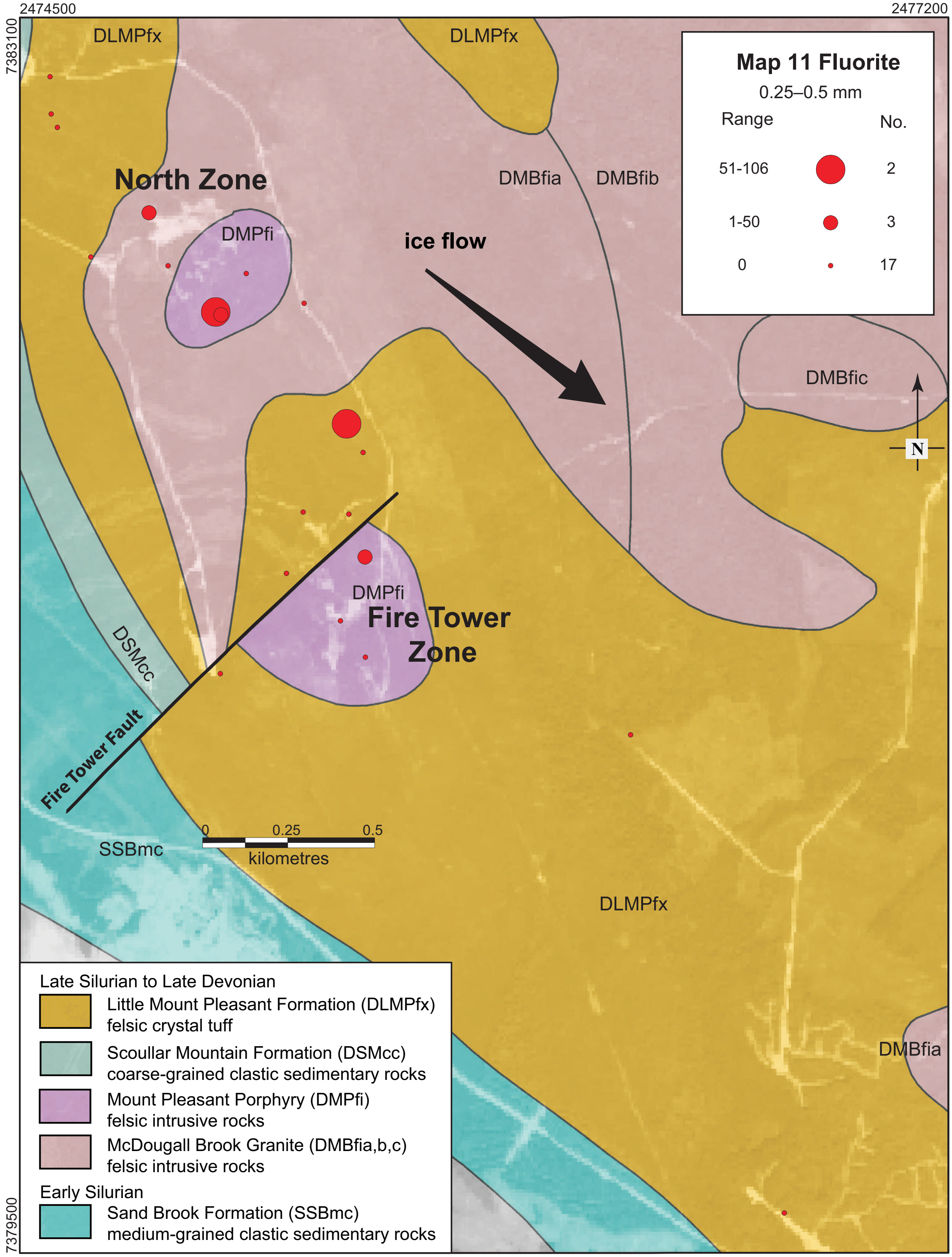
Map 9. Proportional dot map showing topaz abundance in the non-ferromagnetic, >3.2 SG, 1.0–2.0 mm fraction of till samples normalized to a 10 kg weight of <2 mm (table feed). Bedrock geology modified from McLeod et al. (2005).

APPENDIX B continued.



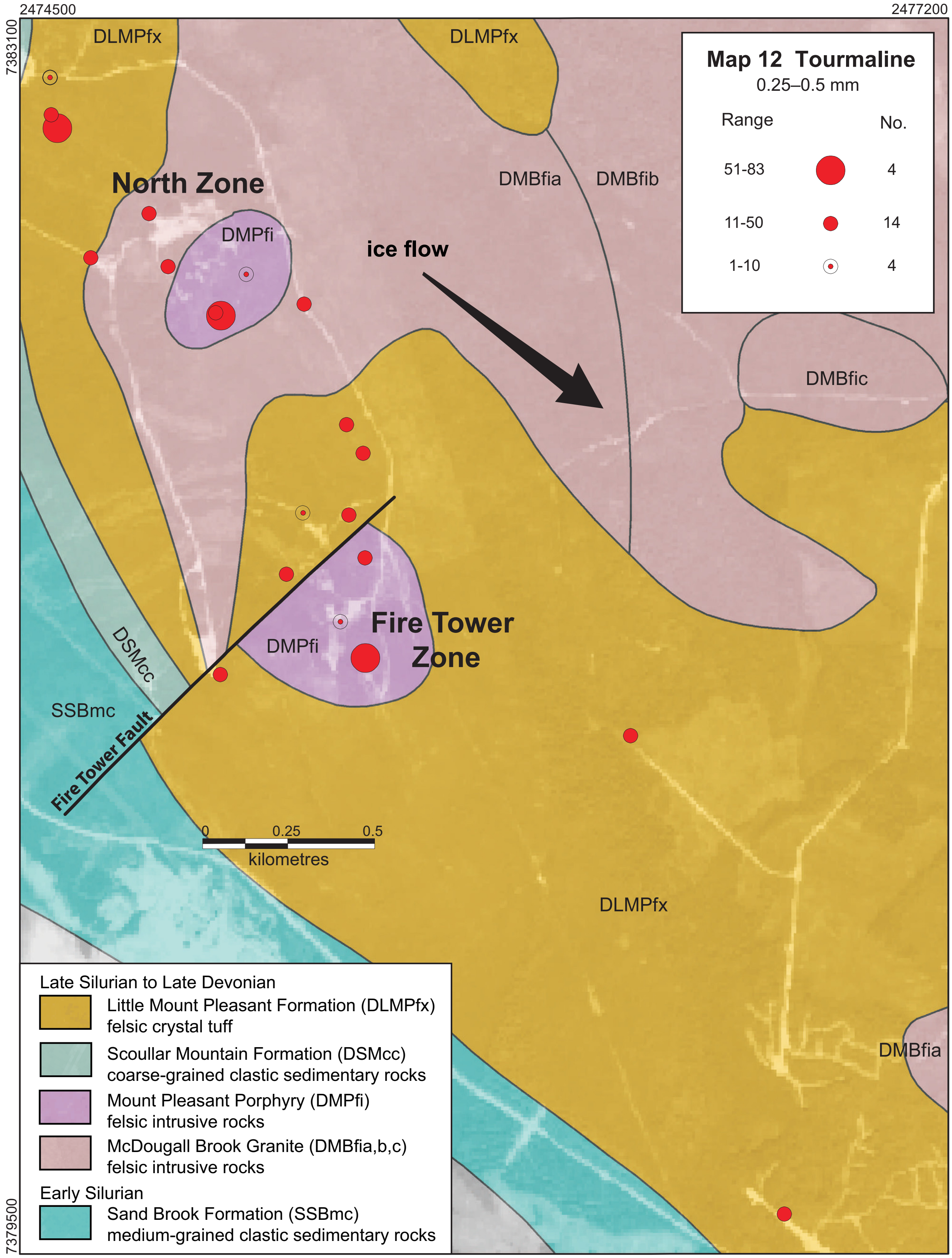
Map 10. Proportional dot map showing pyrite abundance in the non-ferromagnetic, >3.2 SG, 0.25–0.5 mm fraction of till samples normalized to a 10 kg weight of <2 mm (table feed). Bedrock geology modified from McLeod et al. (2005).

APPENDIX B continued.



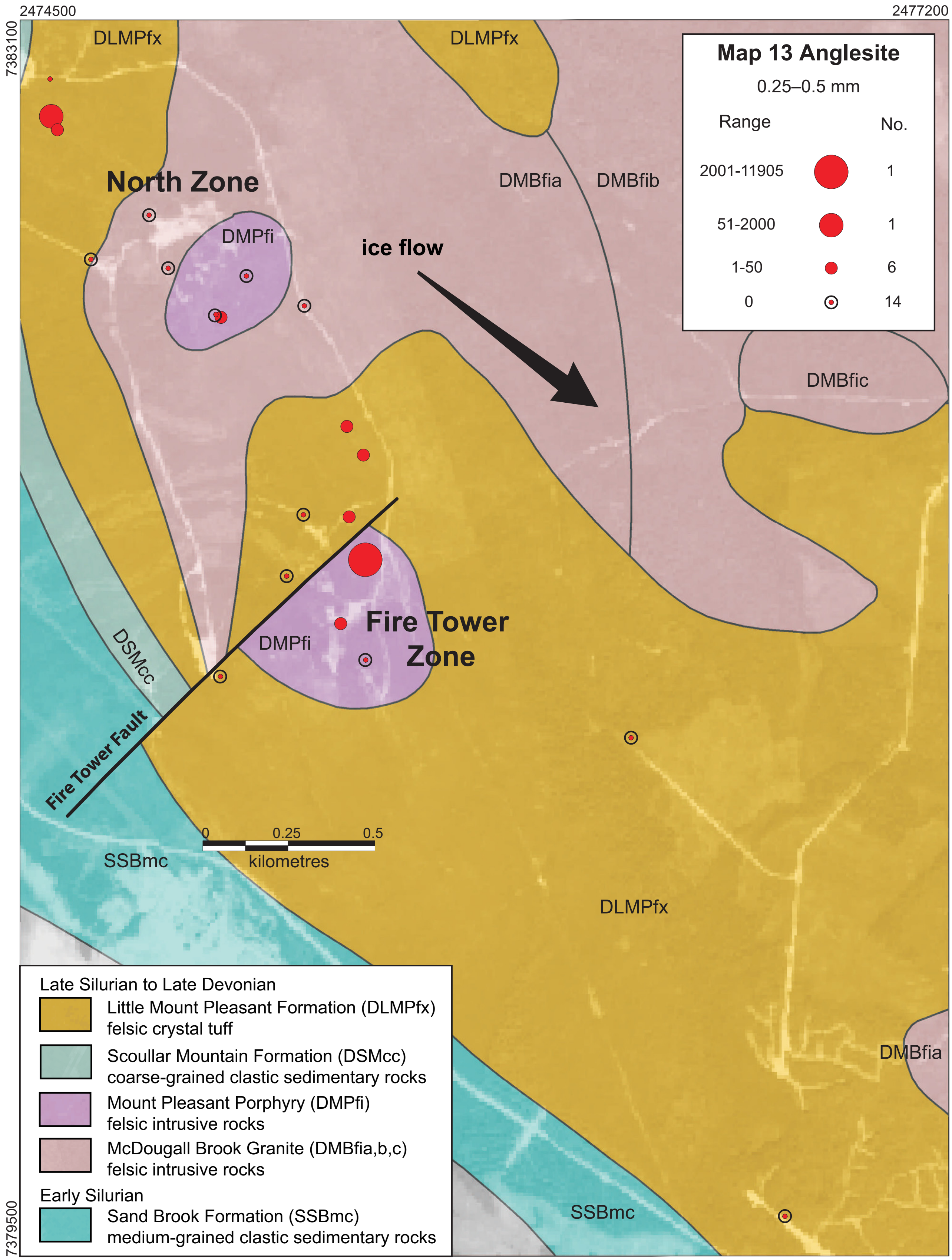
Map 11. Proportional dot map showing fluorite abundance in the non-ferromagnetic, 3.0–3.2 SG, 0.25–0.5 mm fraction of till samples normalized to a 10 kg weight of <2 mm (table feed). Bedrock geology modified from McLeod et al. (2005).

APPENDIX B continued.



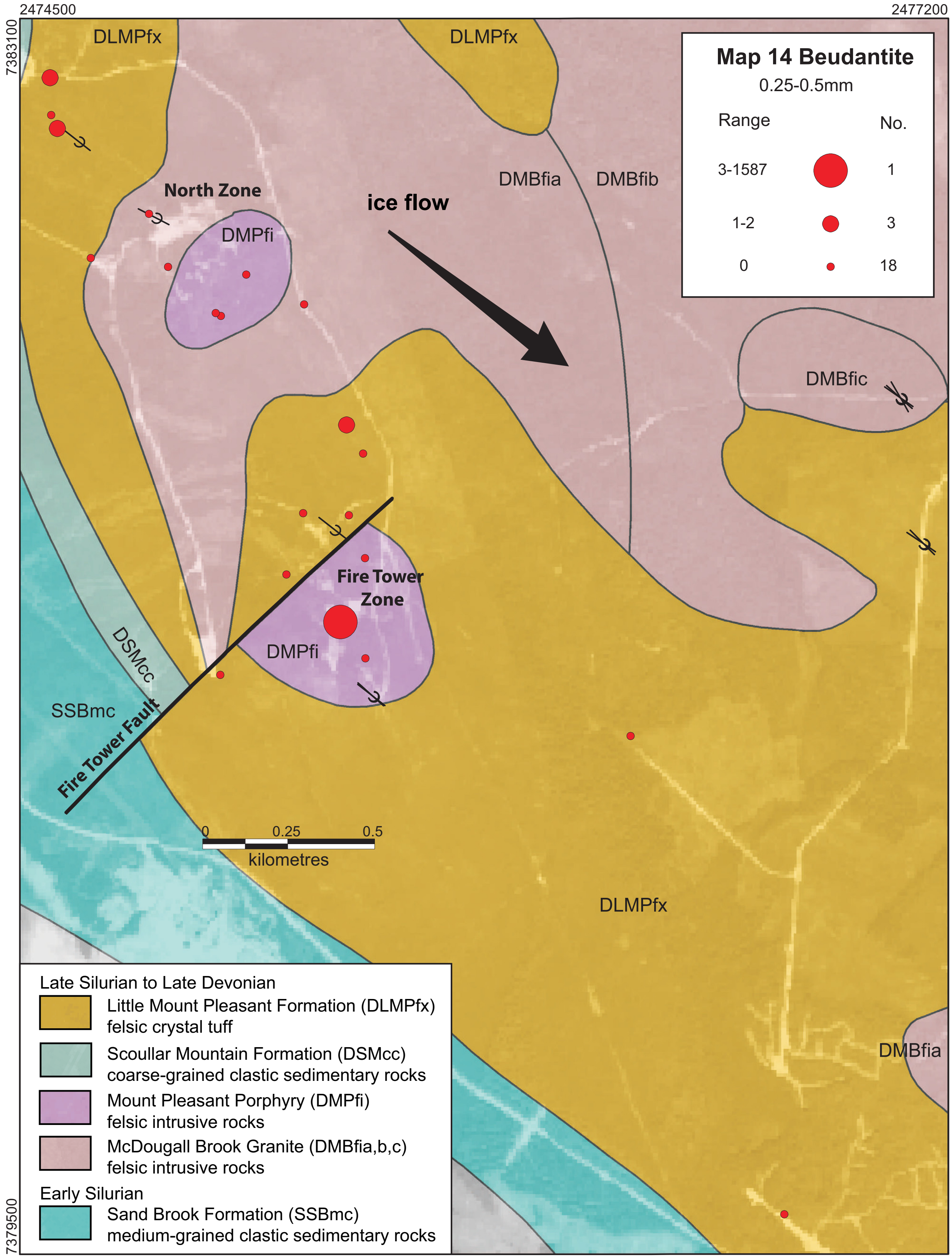
Map 12. Proportional dot map showing tourmaline abundance in the non-ferromagnetic, 3.0–3.2 SG, 0.25–0.5 mm fraction of till samples normalized to a 10 kg weight of <2 mm (table feed). Bedrock geology modified from McLeod et al. (2005).

APPENDIX B continued.



Map 13. Proportional dot map showing anglesite abundance in the non-ferromagnetic, >3.2 SG, 0.25–0.5 mm fraction of till samples normalized to a 10 kg weight of <2 mm (table feed). Bedrock geology modified from McLeod et al. (2005).

APPENDIX B continued.



Map 14. Proportional dot map showing beudantite abundance in the non-ferromagnetic, >3.2 SG, 0.25–0.5 mm fraction of till samples normalized to a 10 kg weight of <2 mm (table feed). Bedrock geology modified from McLeod et al. (2005).