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Résumé de l'article

The Canaan River pluton comprises megacrystic monzogranite and quartz diorite to monzodiorite that is exposed in several small inliers on the Carboniferous New Brunswick Platform west of Moncton in southeastern New Brunswick. Its distinct geophysical signature and borehole data suggest that the Canaan River pluton is part of a large buried felsic to mafic intrusive body that lies at relatively shallow depths beneath flat-lying Pennsylvanian sandstone on the platform. New laser ablation ICP-MS in situ analysis of the megacrystic monzogranite yielded a U-Pb zircon concordia age of 412.6 ± 2.1 Ma, indicating that the intrusion is of Early Devonian (upper Lochkovian) age. The new radiometric data along with lithological, geochemical, and isotopic data suggest that the Canaan River pluton is most like the megacrystic Hawkshaw Granite of upper Lochkovian age in the Pokiok Batholith in southwestern New Brunswick. The similarities shown by these granites suggests that they may have been generated in the same complex tectonomagmatic setting related to the successive arrival of the leading edge of Ganderia and Avalonia at the composite Laurentian margin during the Salinic and Acadian orogenies.

U–Pb (zircon) age, petrology, and tectonic setting of the Canaan River pluton, southeastern New Brunswick, Canada

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ABSTRACT

The Canaan River pluton comprises megacrystic monzogranite and quartz diorite to monzodiorite that is exposed in several small inliers on the Carboniferous New Brunswick Platform west of Moncton in southeastern New Brunswick. Its distinct magnetic geophysical signature and borehole data suggest that the Canaan River pluton is part of a large buried felsic to mafic intrusive body that lies at relatively shallow depths beneath flat-lying Pennsylvanian sandstone on the platform. New laser ablation ICP-MS in situ analysis of the megacrystic monzogranite yielded a U–Pb zircon concordia age of 412.6 ± 2.1 Ma, indicating that the intrusion is of Early Devonian (upper Lochkovian) age.

The new radiometric data along with lithological, geochemical, and isotopic data suggest that the Canaan River pluton is most like the megacrystic Hawkshaw Granite of upper Lochkovian age in the Pokiok Batholith in southwestern New Brunswick. The similarities shown by these granites suggests that they may have been generated in the same complex tectonomagmatic setting related to the successive arrival of the leading edge of Ganderia and Avalonia at the composite Laurentian margin during the Salinic and Acadian orogenies.

RÉSUMÉ

Le pluton de la rivière Canaan est constitué de monzogranite mégacristallin et de diorite quartzique passant à de la monzodiorite exposée dans plusieurs petites boutonnières de la plateforme carbonifère du Nouveau-Brunswick, à l'ouest de Moncton, dans le sud-est du Nouveau-Brunswick. Sa signature géophysique magnétique distinctive et les données de puits de forage permettent de supposer que le pluton de la rivière Canaan représente une partie d'une masse intrusive felsique à mafique de forte dimension enfouie, reposant à une profondeur relativement faible sous le grès pennsylvanien horizontal de la plateforme. Une nouvelle analyse in situ par ICP-MS avec ablation au laser a attribué au monzogranite macrocristallin un âge U–Pb sur zircon concordia de 412.6 ± 2.1 Ma, ce qui révèle que l'intrusion remonte au Dévonien précoce (Lochkovien supérieur).

Les nouvelles données radiométriques tout comme les données lithologiques, géochimiques et isotopiques laissent présumer que le pluton de la rivière Canaan est très semblable au granite mégacristallin de Hawkshaw, qui remonte au Lochkovien supérieur, dans le batholite de Pokiok, dans le sud-ouest du Nouveau-Brunswick. Les similarités entre les granites laissent supposer qu'ils pourraient avoir été produits au sein du même cadre tectonomagmatique complexe apparenté à l'arrivée successive des fronts de la Ganderie et de l'Avalonie le long de la marge composite laurentienne durant les orogénèses salinique et acadienne.

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INTRODUCTION AND REGIONAL GEOLOGY

The Canaan River pluton is located on Canaan River and in the surrounding area, about 40 km west of Moncton in southeastern New Brunswick (Fig. 1). Hamilton (1962) was

the first to describe the megacrystic granite on Canaan River west of Moncton (Fig. 1), but since then very little work has been done. Whalen *et al.* (1986) named the granite the Canaan River pluton and sampled it as part of a larger isotopic and geochemical study. More detailed mapping of the

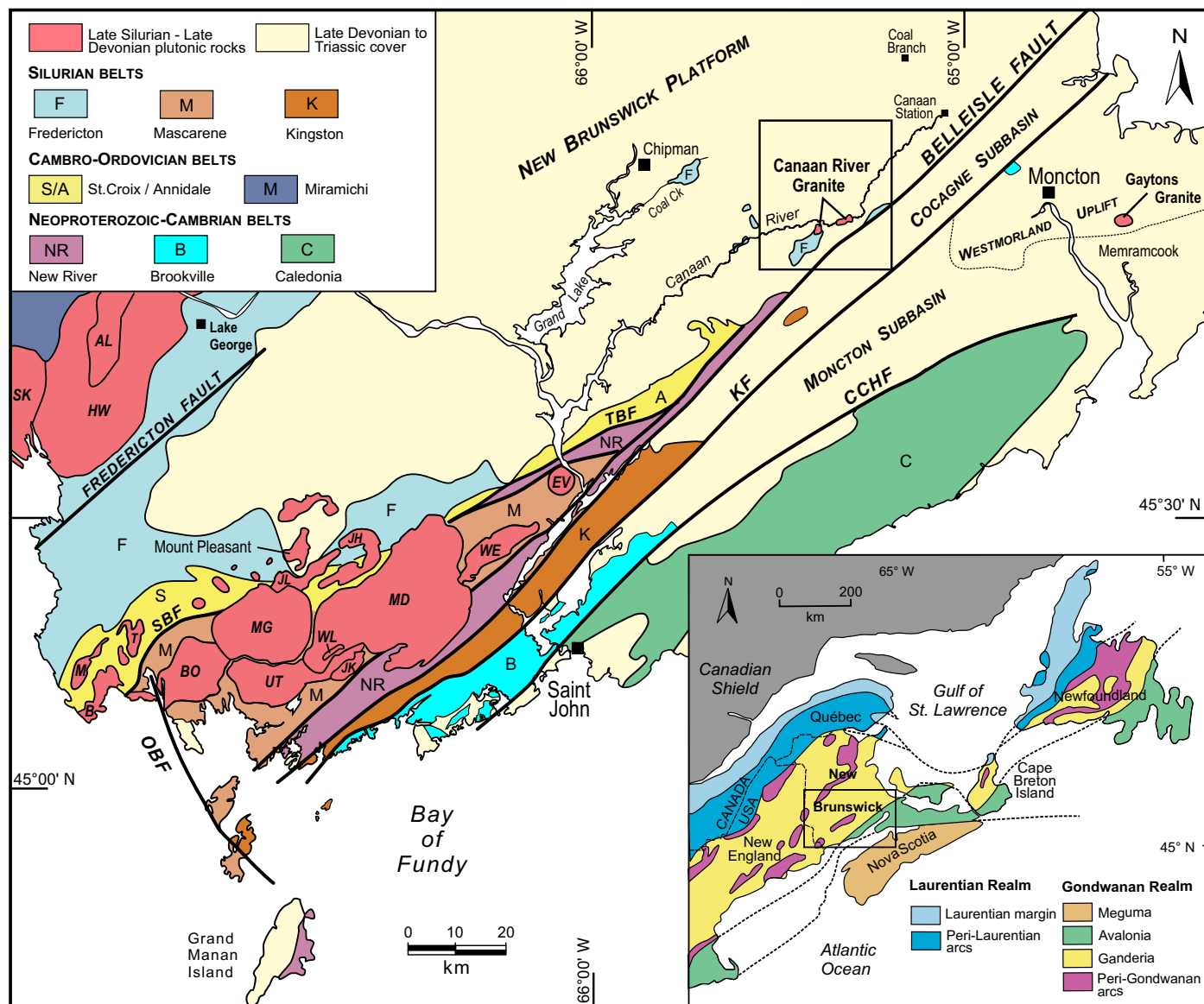


Figure 1. Map of southern New Brunswick showing major geological subdivisions and Silurian and Devonian plutonic rocks. Area outlined in black is location of figures 2 and 3. Inset map shows major tectonic elements of the northern Appalachian orogen in New England and Atlantic Canada; the area of southern New Brunswick shown in Figure 1 outlined by the box. List of Saint George Batholith unit abbreviations: B – Baring; BO – Bocabec; EV – Evandale; HW – Hawkshaw; JH – Jimmy Hill; JK – Jake Lee Mountain; JL – John Lee Brook; M – Mohannis; MD – Mount Douglas; MG – Magaguadavic; SK – Skiff Lake; T – Tower Hill; UT – Utopia; WE – Welsford; WL – Wellington Lake. List of fault name abbreviations: CCHF – Caledonia-Clover Hill; KF – Kennebecasis; OBF – Oak Bay; SBF – Sawyer Brook; TBF – Taylors Brook.

Paleozoic inliers and surrounding Carboniferous rocks was conducted by St. Peter and Johnson (2006; 2008) and Johnson and St. Peter (2008), but the pluton has never been formally named.

The Canaan River area is largely underlain by flat-lying Pennsylvanian sandstone that is part of the Carboniferous New Brunswick Platform of Poole (1967), an area of uplifted Early Paleozoic basement within the larger Late Devonian to Lower Permian Maritimes Basin of Atlantic Canada (Rolf 1962; Bradley 1982; Gibling *et al.* 2008). The platform covers an area of over 25 000 km² and forms the roughly tri-

angular area of Pennsylvanian Pictou Group that is exposed at surface over much of the eastern part of the province. The Pictou Group either disconformably overlies Mississippian red beds and peralkaline volcanic rocks or lies directly on pre-Carboniferous basement, as is the case with the Canaan River pluton (Ball *et al.* 1981; Fyffe and Barr 1986; Gray *et al.* 2010).

Pre-Carboniferous inliers are restricted to the southern parts of the platform between Chipman and Canaan River near the boundary between the New Brunswick Platform and the Cocagne Subbasin (Fig. 1). In addition to granite,

thick turbidite sequences belonging to the Silurian Kingsclear Group of the Fredericton belt (e.g., Fyffe *et al.* 2011) and minor diorite are also exposed. These inliers are the surface expression of a shallow-buried basement high referred to as the “Minto-Chipman/Canaan River basement high”, which was delineated by a series of shallow boreholes that were drilled during a study to determine the coal potential of the Pennsylvanian rocks (Ball *et al.* 1981). Twelve of the boreholes that were drilled in the Chipman and Canaan River areas intersected granodiorite, slate, phyllite, and schist at depths of less than 122 m beneath the Pennsylvanian cover. The distribution of the boreholes that intersected pre-Carboniferous rocks indicated that the boundaries of the basement high are in part controlled by parallel, northwest-trending faults, suggesting a horst-like structure (Ball *et al.* 1981). A regional aeromagnetic survey subsequently revealed prominent, parallel, northwest-trending linear magnetic highs, one of which appears to mark the western boundary of the predicted basement horst (Kiss *et al.* 2004a, 2004b, 2004c). These positive linear magnetic features were interpreted to be mafic dykes intruded into northwest-trending structures, possible feeders to Mississippian volcanic rocks present west of the Canaan River area (Thomas and Kiss 2005). Subsequent mapping has shown that in most cases the bedrock at surface directly over the linear magnetic anomalies is part of the Pictou Group, thus indicating that the dykes are at least in part buried at shallow depths beneath the sandstone cover (St. Peter and Johnson 2006; Johnson and St. Peter 2008). One exception is on Coal Creek (Fig. 1), where a less prominent, northwest-trending linear magnetic anomaly oblique to the main trend of interpreted dykes is related to a lamprophyre dyke in the Flume Ridge Formation of the Kingsclear Group (St. Peter and Johnson 2008).

The boundary between the New Brunswick Platform and the Cocagne Subbasin to the southeast (Gussow 1953; St. Peter and Johnson 2009) is the northeast-striking Belleisle Fault (Fig. 1). In southwestern New Brunswick where Carboniferous cover is lacking, the Belleisle Fault separates Neoproterozoic and Early Paleozoic rocks of the New River, St. Croix, and Annidale belts and Silurian rocks of the Mascarene and Fredericton belts to the west, from the Early Silurian Kingston belt on the east (Barr *et al.* 2002; White *et al.* 2006; Fyffe *et al.* 2011). Immediately west of the Belleisle Fault, the Neoproterozoic and younger rocks are intruded by Late Silurian to Late Devonian granitic to gabbroic plutons of the Saint George Batholith, and even farther west by the Pokiok Batholith (Fig. 1).

The purpose of this paper is to present a U–Pb (zircon) age for a sample of megacrystic granite collected from the Canaan River pluton on Thornes Brook (Fig. 2) and to compare its chemical characteristics to plutons of similar age in southern New Brunswick.

CANAAN RIVER PLUTON

Location and distribution

The Canaan River pluton occurs in several small inliers on Canaan River and its tributary Thornes Brook in the Cherryvale – New Canaan area (Fig. 2). The largest exposures are on Canaan River north of route 112 at New Canaan where megacrystic granite outcrops sporadically along the river bank for about 700 m. At those locations the granite is overlain by nearly horizontal beds of Pennsylvanian sandstone and pebbly conglomerate of the Minto Formation. A separate inlier about 1.5 km to the west consists of dark grey diorite cut by felsic veins and pods. On Thornes Brook, megacrystic granite is exposed in three separate inliers between 2 and 3 km south of its junction with Canaan River (Fig. 2). At the southernmost location the granite intruded graded feldspathic wacke and dark grey to black siltstone and shale of the Early Silurian Digdeguash Formation of the Kingsclear Group (St. Peter and Johnson 2006; Johnson and St. Peter 2008).

Although the majority of surface exposures in the Canaan River area are Carboniferous sandstone, the aeromagnetic signature suggests that the intrusive rocks are part of a much larger plutonic complex buried beneath a relatively thin cover of Carboniferous rocks. This is illustrated on the aeromagnetic map, which shows the granite and diorite on Canaan River clearly evident as magnetic low and high areas, respectively (Fig. 3). Based on the strength and arcuate shape of the aeromagnetic response, Thomas and Kiss (2005) proposed that a large mafic/felsic intrusive complex underlies an area of over 200 km². A coincident positive gravity anomaly associated with the intrusive complex (Thomas and Kiss 2005; their figure 19) suggests that the mafic components are predominant. An obvious truncation of the magnetic highs associated with the Digdeguash Formation by the Canaan River intrusive complex is also evident on the magnetic map (Fig. 3). A northwest-trending, linear magnetic high interpreted to be a mafic dyke is also apparent in the upper left corner on Figure 3. As previously noted, similar northwest-trending dykes delineate the boundaries of horst and graben structures to the west and here it appears to partially cut the arcuate magnetic high associated with the intrusion. Although not shown, a positive gravity anomaly associated with the mafic rocks in the intrusive complex is also truncated sharply to the east along this lineament. It is interesting to speculate that the semicircular magnetic high that is cut-off at the northern map boundary is the continuation of the Canaan River intrusive complex that has been offset sinistrally by a northwest-trending fault; unfortunately, no deep borehole data are available in this area to confirm or refute this hypothesis.

The boreholes drilled in the area indicate that the thickness of Carboniferous sandstone overlying the intrusion is variable. Granite and granodiorite were encountered at 30 and 40 m below surface in boreholes 219 and 220 near Canaan River, but only 9 km to the north, boreholes 172 and

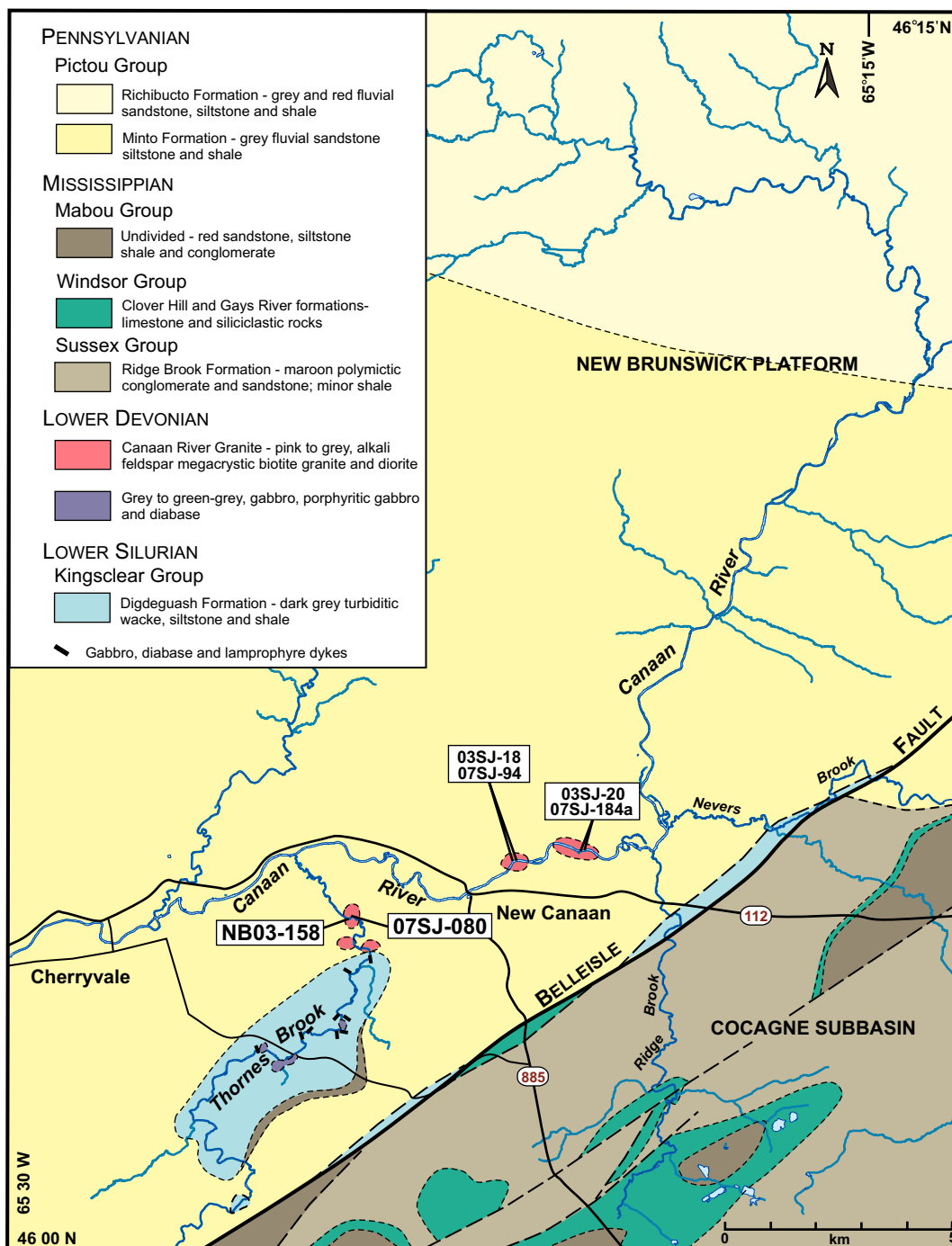


Figure 2. Bedrock geological map of the southeastern New Brunswick Platform and Cocagne Subbasin. Numbers denote the locations of geochronological and geochemical samples.

196 to 198 penetrated Carboniferous sandstone for the entire depth of 122 m, although the magnetic response is still quite strong in that area (Fig. 3). Granite was intersected even deeper in hydrocarbon exploration boreholes drilled nearly 40 km to the northeast at Canaan Station and Coal Branch (Fig. 1), at depths of 330 and 362 m, respectively. Based on gravity data and the presence of fresh biotite and hornblende in the cuttings, St. Peter and Fyffe (1990) argued that the granite encountered in these deep boreholes is likely

part of a buried Devonian pluton that is contiguous with the Canaan River pluton.

Petrography

The main textural variety in the Canaan River pluton is pink to grey, very coarse- to medium-grained monzogranite containing potassium feldspar phenocrysts up to 6 cm in length, although 2 cm is more common (Fig. 4a). The

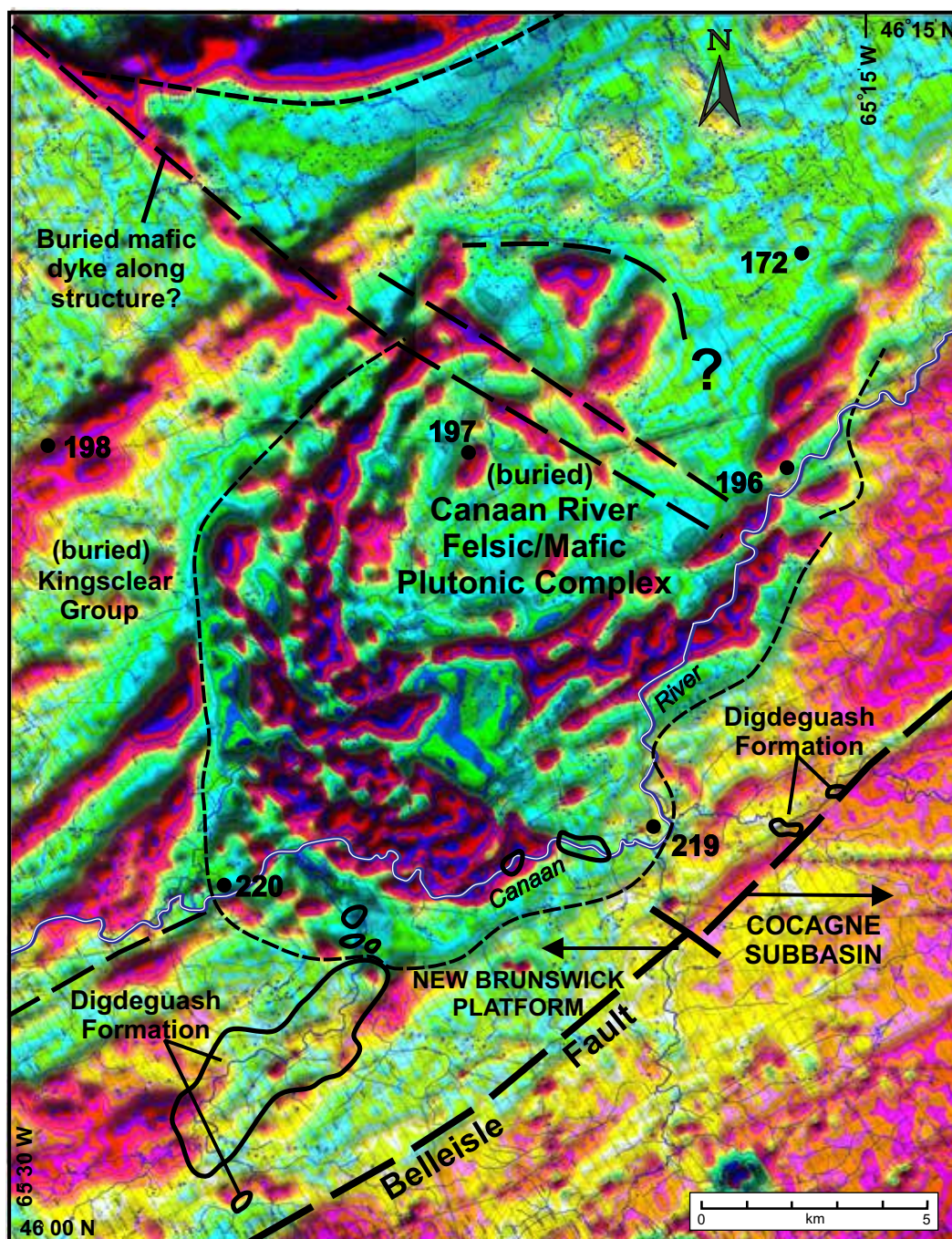


Figure 3. First vertical derivative magnetic map showing the same area as in Figure 2. Geophysical interpretation modified from Thomas and Kiss (2004) shows interpreted contacts of the Canaan River composite pluton (dashed black lines) beneath Pennsylvanian cover. Solid black lines show areas on the New Brunswick Platform where pre-Carboniferous outcrop was observed, including the Canaan River pluton. Black circles with numbers show location of boreholes with borehole catalogue number (<http://www1.gnb.ca/0078/GeoscienceDatabase/Borehole/Search.asp>).

monzogranite consists of approximately equal amounts of plagioclase, orthoclase, and quartz, and about 10% biotite. Apatite and zircon are abundant accessory phases, mainly as inclusions in biotite (Figs. 4b, c). Opaque phases are rare. Pink to grey aplite, biotite-rich fine-grained granite and microgranite porphyry dykes, and locally pegmatitic feldspar dykes were observed to have cut the monzo-

granite. On Thornes Brook the monzogranite contains large xenoliths of garnet-bearing metasedimentary rocks likely derived from the adjacent Digdeguash Formation. The latter contains abundant dykes of dark grey, fine-grained to medium-grained gabbro and plagioclase porphyry (Fig. 2), but the relationship of these mafic dykes to the Canaan River pluton is not known.

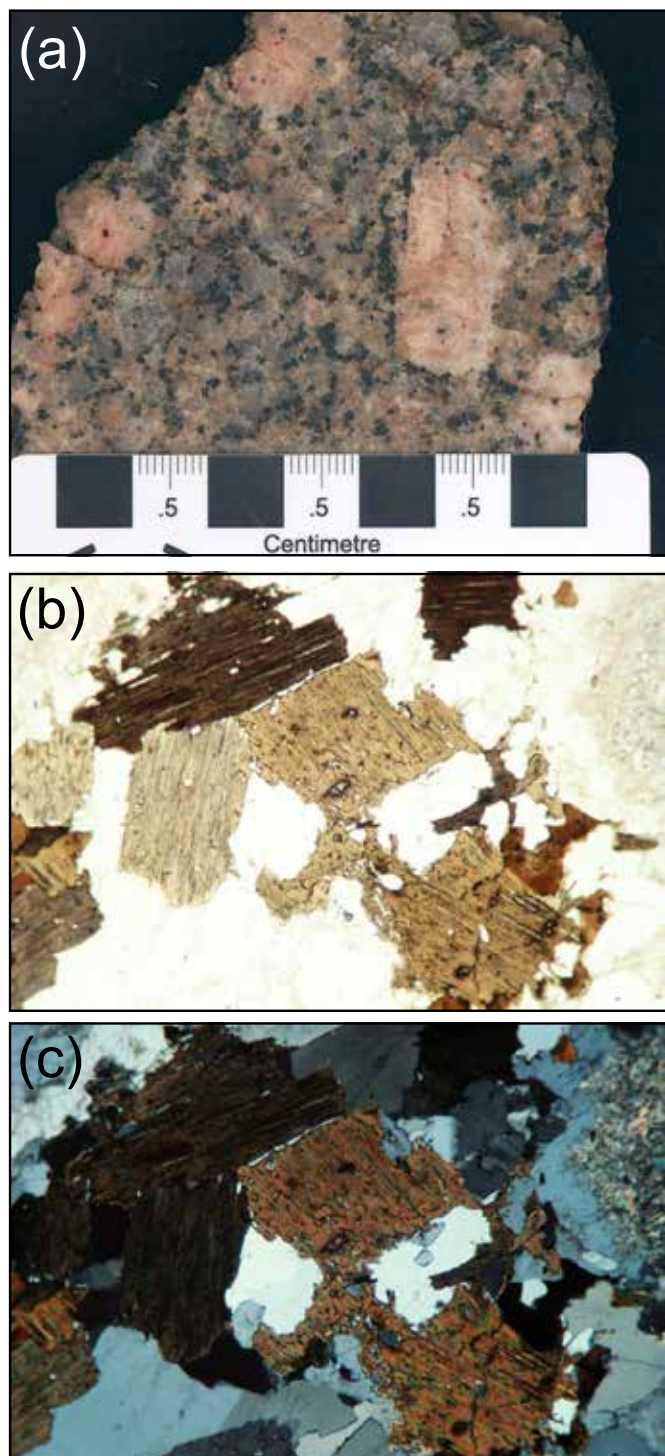


Figure 4. (a) Photograph of a cut slab from dated sample 07SJ-80 showing large alkali-feldspar megacrysts. (b) Photomicrograph of sample NB03-158 in plane polarized light; width of image is about 3 mm. Image shows quartz (clear), plagioclase, and biotite (shades of brown) partly altered to chlorite. Biotite has abundant inclusions of apatite (white) and zircon (high relief). (c) Same as (b) except with crossed polars.

The dioritic inlier in Canaan River consists of dark grey, medium-grained quartz diorite to monzodiorite with felsic pods and veins. The rock consists of plagioclase, quartz, microcline, hornblende, and biotite, with accessory apatite, titanite, and magnetite.

LASER ABLATION ICP-MS U-PB GEOCHRONOLOGY

Methods

A 1 kg sample (07SJ-080) of megacrystic granite from the Canaan River pluton was sent to Overburden Drilling Management (ODM) in Ottawa, Ontario, for electro-pulse disaggregation and initial zircon separation. Zircon grains for dating were then picked from the zircon concentrates at Cape Breton University. Selected grains were mounted in an epoxy-covered thin section at the University of New Brunswick, Fredericton, polished to expose the centres of the zircon grains, and imaged using cold cathodoluminescence to identify internal zoning and inclusions. These images were used to select ablation points (30 μm diameter), avoiding any visible inclusions, cracks, or other imperfections.

U and Pb isotopic compositions were measured using the Resonetics S-155-LR 193 nm Excimer laser ablation system connected to an Agilent 7700 \times quadrupole inductively coupled plasma – mass spectrometer in the Department of Earth Sciences at the University of New Brunswick, following the procedure outlined by McFarlane and Luo (2012). Data reduction was done in-house using Iolite software (Paton *et al.* 2011) to process the laser output into data files, and further reduced for U–Pb geochronology using VizualAge (Petrus and Kamber 2012). VizualAge outputs included uncorrected U–Pb ratios that were used to calculate ^{204}Pb -based corrections (Andersen 2002) and ^{208}Pb -based corrections. Data were filtered using ^{204}Pb as a monitor. In this sample no corrections were applied to any data, which are presented in the Appendix, where those used in calculating the concordia age reported below are highlighted. Data points included in the concordia calculations and reported here are grains that are 98% to 101% concordant and do not require a correction for common Pb ($^{204}\text{Pb} < 80$ counts per second).

Concordia ages were calculated using Isoplot versions 3.75 and 4.15 (Ludwig 2003, 2012). Ages are reported at 95% confidence, with decay-constant errors included in the calculations. The calculated concordia ages overlap with the weighted mean ages for the samples using all near-concordant data. $^{206}\text{Pb}/^{238}\text{U}$ ages are used in all the probability distribution calculations. The calculated concordia ages for reference materials FC1 and Plesovice during this analytical run are 1098.8 ± 2.5 Ma and 337.9 ± 2.4 Ma respectively, data for all reference materials are included in the Appendix.

Results

The zircon grains in sample 07SJ-080 range from dark

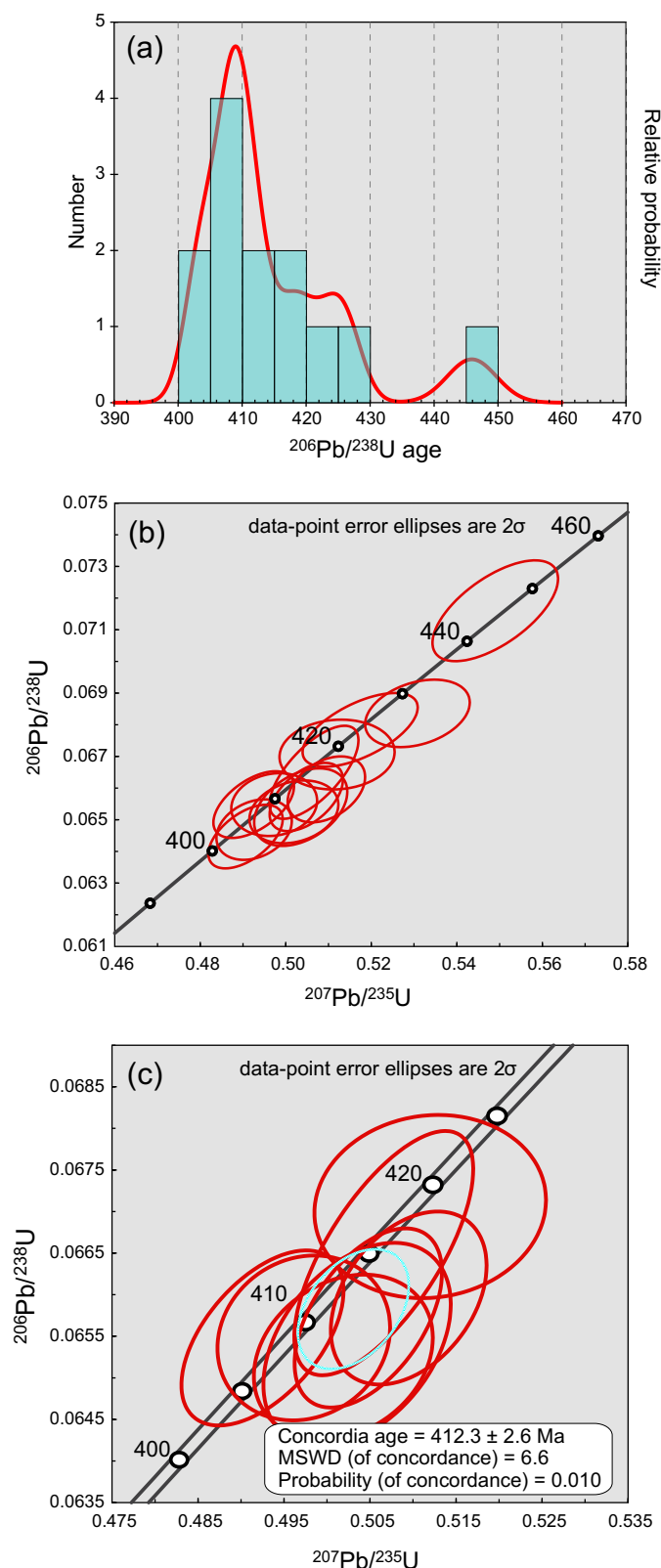


Figure 5. (a) Histogram (blue) and probability plot (red line) showing $^{206}\text{Pb}/^{238}\text{U}$ zircon ages that are 98–101% concordant. (b) Concordia diagram showing data that are 98–101% concordant. (c) Concordia diagram using 8 concordant grains that yielded a concordia age of 412.3 ± 2.6 Ma. Abbreviation MSWD is mean square of weighted deviates.

yellow to clear and are acicular to elongate and euhedral in shape. Most of the grains are $<30\ \mu\text{m}$ in size, but larger grains in the $50\text{--}100\ \mu\text{m}$ range were picked for analysis. In CL most of the larger grains show clear oscillatory zoning typical of igneous zircon grains. The $^{206}\text{Pb}/^{238}\text{U}$ ages of grains between 98% and 101% concordant range between ca. 400 Ma and 425 Ma with one older grain at ca. 445 Ma (Figs. 5a and b). The main cluster of near-concordant grains ($n = 8$) yielded a concordia age of 412.3 ± 2.6 Ma (Fig. 5c), which we interpret as the best estimate of the igneous crystallization age of the rock. While both the MSWD and probability of concordance can be improved by using fewer grains in the concordia calculation, we prefer the approach of including as many grains as possible in order to get a representative concordia age. This concordia age overlaps with the weighted mean age of all the 98–101% concordant grains at 411.5 ± 4.7 Ma at 95% confidence. Three older grains with $^{206}\text{Pb}/^{238}\text{U}$ ages of 423.1, 426.3 and 445.9 are interpreted as either inherited or anticyclic grains formed from essentially comagmatic and related magma. Younger discordant grains are interpreted as results of Pb loss.

GEOCHEMISTRY

Four samples of megacrystic monzogranite and two samples of diorite were selected from the Canaan River pluton for whole-rock chemical analysis (Table 1). All samples were analyzed for major and trace elements, and three of the samples (two of monzogranite and one of diorite) also for rare-earth elements. Analyses for one additional sample of megacrystic granite (P9-WXNB353) from Whalen *et al.* (1996) were also utilized. To facilitate discussion of the geochemistry, analyses for granites of similar Lower Devonian (upper Lochkovian) age in the Saint George Batholith (John Lee Brook and Wellington Lake plutons) and Pokiok Batholith (Hawkshaw Granite) were plotted on the geochemical diagrams for comparison. The analyses for the John Lee Brook Granite include samples 85MM154B, 7f1/87 and 7g76/87 from McLeod (1990) and P8-WXNB350 from Whalen *et al.* (1996). The one set of analyses from the Wellington Lake Granite (sample 15-72) is from Mohammadi *et al.* (2017). The set of twelve analyses for the Hawkshaw Granite are from Whalen (1993).

The five monzogranite samples from the Canaan River pluton range in SiO_2 content between 67% and 70%, and the two quartz diorite samples have 55% and 59% SiO_2 (Table 1). Based on major-element components, the felsic rocks vary from granite to quartz monzonite and granodiorite; the Canaan River dioritic samples are quartz monzodiorite (Fig. 6a). The Canaan River and all of the other upper Lochkovian age granite samples plot in the high-K field on the silica versus K_2O diagram with the exception of the shoshonitic Wellington Lake Granite (Mohammadi *et al.* 2017) (Fig. 6b). On the aluminum saturation index (ASI) diagram, the Canaan River monzogranite samples plot in and near the field defined by chemical data from twelve samples of the

Table 1. Major and trace element compositions of samples from Canaan River pluton. Coordinates are UTM Zone 20.

Sample	07SJ-80	07SJ-184a	NB03-158	03SJ-20	03SJ-18	07SJ-94
Easting	314368.4	319480.2	314346.4	319477	318137	318110
Northing	5104256	5105678.8	5104252.9	5105728	5105462	5105488
Major oxides (wt. %)						
SiO ₂	67.42	69.97	69.39	67.78	58.82	55.30
TiO ₂	0.52	0.41	0.39	0.45	1.03	1.23
Al ₂ O ₃	14.84	15.21	14.72	15.52	16.68	16.09
Fe ₂ O ₃	4.45	3.30	3.30	3.34	6.29	8.11
MnO	0.12	0.08	0.09	0.08	0.13	0.17
MgO	0.95	0.69	0.71	0.75	3.51	4.14
CaO	2.50	1.80	1.63	2.10	6.28	6.45
Na ₂ O	3.50	3.15	3.11	3.29	3.65	3.61
K ₂ O	3.40	5.12	4.19	4.85	2.22	2.66
P ₂ O ₅	0.17	0.13	0.14	0.14	0.34	0.33
Total	98.70	100.60	99.16	98.81	99.64	99.02
Trace elements (ppm)						
Rb	154	173	172	166	66	86
Cs	9.2	4.5				3.4
Ba	632	977	874	926	450	605
Sr	196	181	157	179	385	351
Ga	22	18	18	19	19	21
Ta	1.2	0.9				1.4
Nb	13	10	13	14	15	18
Hf	6.7	5.4				5.1
Zr	223	193	210	194	185	166
Y	30	22	22	32	27	35
Th	15.9	16.9	5	13	6	10.3
U	4.2	3.9	1	5	2	3.1
La	40.1	36.3				39.3
Ce	81.8	70.0				86.1
Pr	10.0	7.3				10.8
Nd	34.3	26.6				37.6
Sm	6.9	6.0				7.7
Eu	1.3	1.4				1.9
Gd	6.2	5.0				6.9
Tb	1.0	0.8				1.1
Dy	5.7	4.3				6.5
Ho	1.1	0.8				1.3
Er	3.2	2.4				3.6
Tm	0.47	0.35				0.52
Yb	2.9	2.1				3.2
Lu	0.44	0.32				0.47
Cr	30	70	5		49	90
Ni	10	20	1.5	34	8	10
Co	6	5	76	48	58	23
Sc	11	8				22
V	49	32	54	60	148	173
Cu	30	20	130		14	30
Pb	30	25	16	38	12	20
Zn	100	30	51	51	72	120

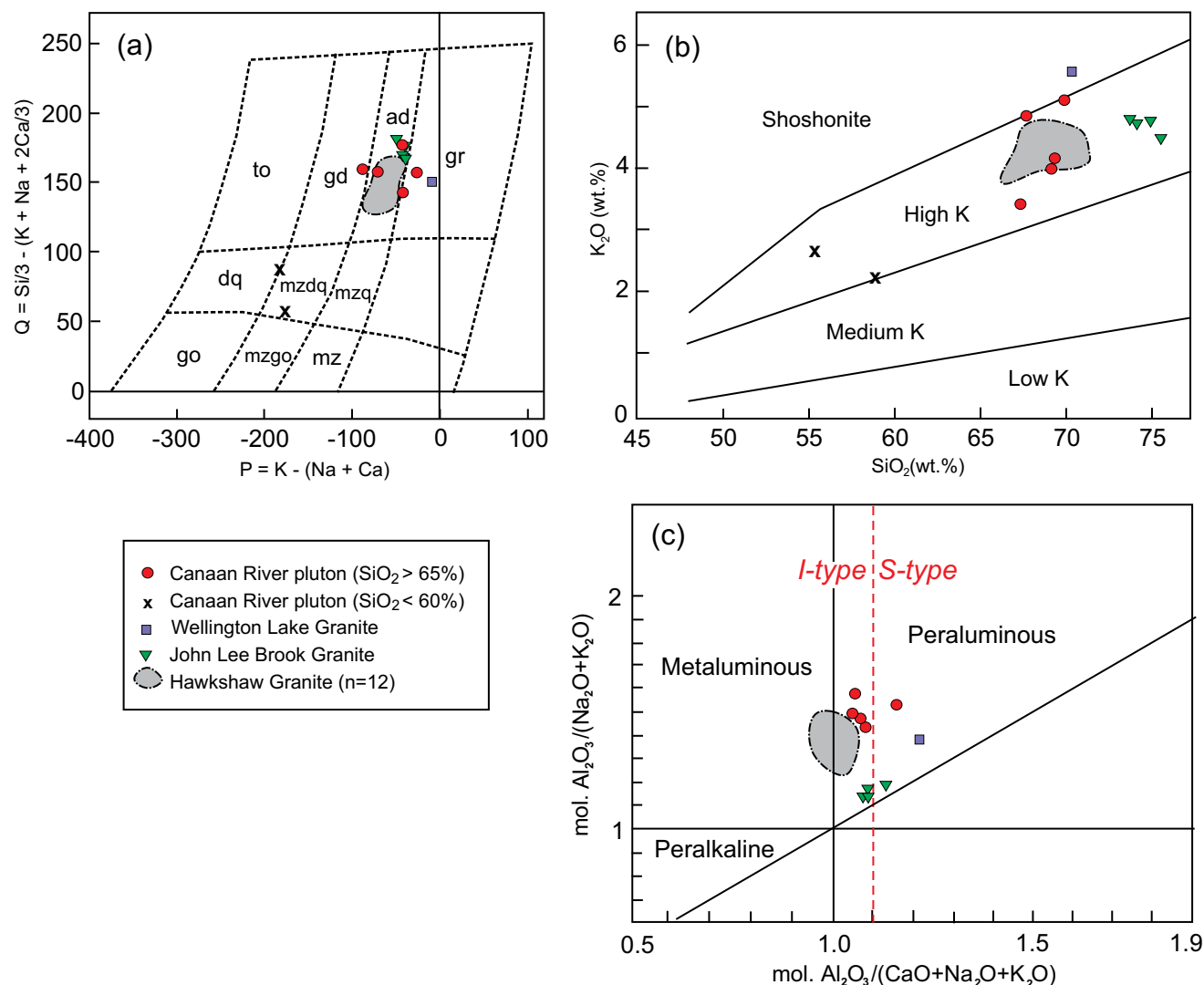


Figure 6. Major element characteristics of megacrystic monzogranite and quartz diorite samples from the Canaan River pluton (Table 1) and temporally equivalent Hawkshaw, John Lee Brook, and Wellington Lake granites (data from McLeod 1990; Whalen 1993; Whalen *et al.* 1996; Mohammadi *et al.* 2017). (a) P-Q classification of Debon and LeFort (1983). Abbreviations: ad – adamellite, dq – quartz diorite, gd – granodiorite, go – gabbro, gr – granite, mz – monzonite, mzq – quartz monzonite, mzdq – quartz monzodiorite, mzgo – monzogabbro, to – tonalite. (b) Silica versus K_2O diagram with fields after Le Maitre *et al.* (1989). (c) Shand aluminium saturation index (ASI) plot with fields after Maniar and Piccoli (1989). Vertical dashed line at ASI = 1.1 Red circles are monzogranite and X symbols are quartz diorite samples.

Hawkshaw Granite from Whalen (1993), although the former samples are slightly more peraluminous (Fig. 6c). The Canaan River samples plot near the upper limit (<1.1) for I-type granite and transitional to S-type granite (Chappell and White 1974, 2001), which is similar to the S-type John Lee Brook Granite, although the latter is slightly more alkaline (Fig. 6c).

Both the felsic and mafic components of the Canaan River pluton exhibit similar rare-earth element (REE) patterns, with enrichment in light REE, small negative Eu anomalies, and relatively flat but slightly decreasing heavy REE profile (Fig. 7a). The overall abundance of REE decreases with increasing SiO_2 content in the samples and is highest in the quartz diorite sample ($\sim 55\% \text{ SiO}_2$) and lowest in the mon-

zogranite sample 07SJ-184a ($\sim 70\% \text{ SiO}_2$), consistent with fractionation of REE-bearing minerals such as apatite and zircon. The quartz diorite also has slightly lower abundances of most large-ion-lithophile elements (LILE), with the exceptions of Sr and Eu (Fig. 7b), consistent with differentiation and fractional crystallization of plagioclase. The Hawkshaw Granite samples show nearly identical trace element patterns, although with lower Ba (Fig. 7b). The John Lee Brook and Wellington Lake granites are also enriched in light REE relative to heavy REE but have much larger negative Eu anomalies than the Canaan River and Hawkshaw (Figs. 7a, c). The single Wellington Lake sample also has the highest absolute abundances of REE consistent with its A-type chemistry (Mohammadi *et al.* 2017). In contrast to

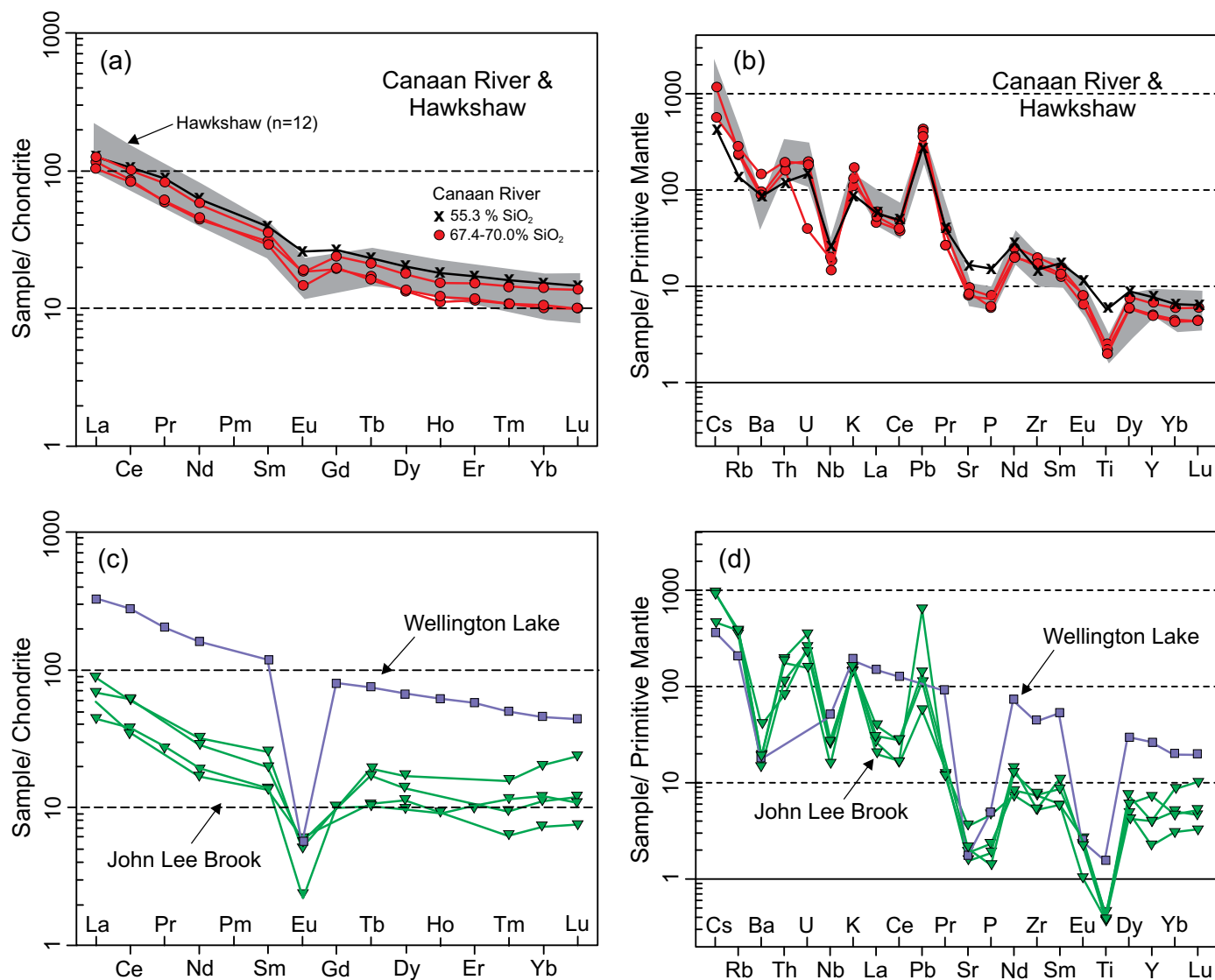


Figure 7. Multi-element diagrams for monzogranite and quartz diorite samples from the Canaan River pluton (Table 1) compared to the Hawkshaw, John Lee Brook, and Wellington Lake granites (data from McLeod 1990; Whalen 1993; Whalen *et al.* 1996; Mohammadi *et al.* 2017). (a) and (c) Chondrite-normalized rare earth element profiles; normalization values are from Boynton (1984). (b) and (d) Primitive mantle-normalized extended element spider diagram; normalization values are from Sun and McDonough (1989).

all of the other samples the majority of John Lee Brook samples are enriched in the heaviest REE (Fig. 7c). The Canaan River, Hawkshaw, and John Lee Brook samples all have negative Nb and Ti anomalies, suggesting a subduction component or assimilation of an upper crustal material (Figs. 7b, d) consistent with the positions of most of the samples in the overlapping volcanic-arc and post-collisional granite fields (Fig. 8a) and in the field for slab failure plutons (Fig. 8b) on tectonic setting discrimination diagrams. Some of the Hawkshaw samples plot toward the within-plate granite field, as does the single Wellington Lake sample, but the latter has significantly higher Y (Fig. 8b).

The Canaan River monzogranite samples plot in or near the boundary of the combined field of I- and S- granites on diagrams that distinguish those granite types from A-type

granitoids but near the upper limit in all of Ga/Al ratio and alkali element oxide and Zr contents (Figs. 9a, b). However, they do not show characteristics of evolved I- and S-type granites (Figs. 9c, d). The Hawkshaw granite dataset overlaps the Canaan River samples on diagrams utilizing Ga/Al ratio and alkali element oxide and Zr contents to distinguish I- and S-type granites from A-type granites (Figs. 9a, b) and are similarly unevolved to slightly more evolved than the Canaan River samples (Figs. 9c, d). In contrast, the Wellington Lake granite plots clearly as A-type (Figs. 9a–d), as determined previously by Mohammadi *et al.* (2017) and the John Lee Brook near the boundary of I- and S-types (Figs. 9a, b), but clearly in the fractionated granite field (Figs. 9c, d).

Mohammadi *et al.* (2017) observed that La/Yb and epsilon Nd values varied systematically across the Saint George

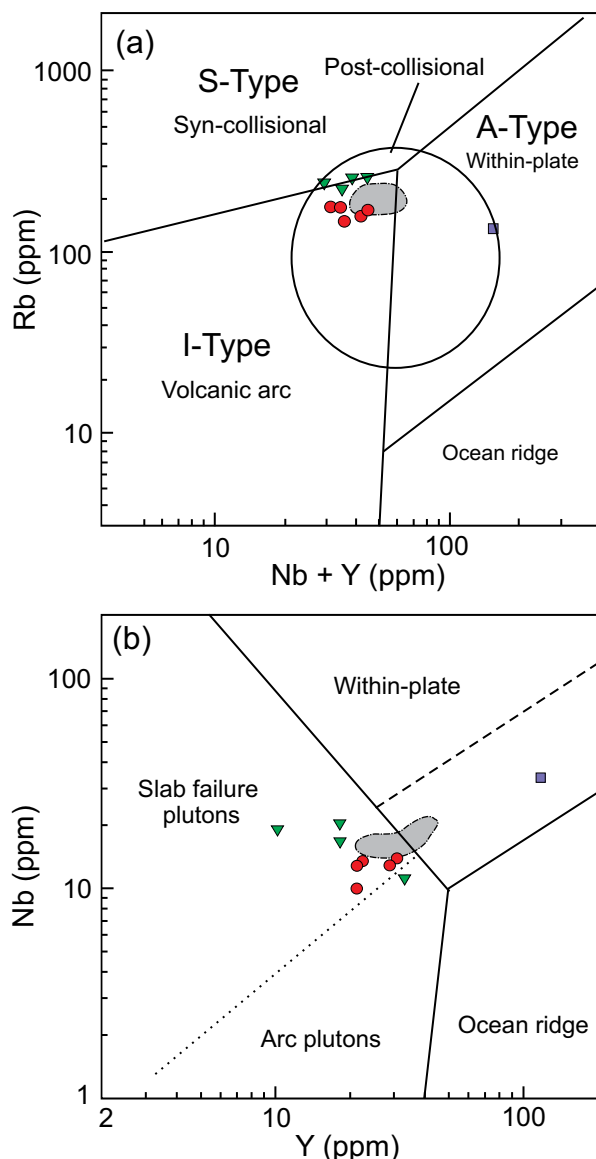


Figure 8. Monzogranite samples from the Canaan River pluton (Table 1) and the Hawkshaw, John Lee Brook, and Wellington Lake granites (data from McLeod 1990; Whalen 1993; Whalen *et al.* 1996; Mohammadi *et al.* 2017) plotted on tectonic setting discrimination diagrams for granitic rocks. Grey shaded field represents 12 samples from the Hawkshaw pluton from Whalen (1993). (a) Rb versus Y + Nb; (b) Nb versus Y. Fields are after Pearce *et al.* (1984), with post-collisional field in (a) from Pearce (1996), S-, I- and A-type granite fields in (a) from Christiansen and Keith (1996) and the slab failure-arc dividing line in (b) from Hildebrand and Whalen (2015).

Batholith from southeast to northwest and demonstrated that the Early Devonian plutons in the northwest have considerably higher La/Yb ratios and lower epsilon Nd values than the Late Silurian plutons in the southeast. The La/Yb values determined for the Canaan River pluton range from 12.3 to 17.3, and therefore are significantly lower than those

of the younger megacrystic Jimmy Hill, Magaguadavic, and Gaytons granites, but are comparable to the John Lee Brook and Hawkshaw granites of similar age (Table 2). However, when comparing the epsilon Nd data, the intrusions in the Saint George Batholith are mostly isotopically positive, ranging from + 3.3 for the A-type Welsford Granite to slightly negative - 0.4 for the S-type Tower Hill pluton (Whalen *et al.* 1994, 1996). In contrast, both the Canaan River and Hawkshaw granites have relatively high isotopically negative epsilon Nd values of - 2.0 and - 2.5, respectively, indicating that melting of supracrustal material was involved in the generation of both of these granites (Whalen *et al.* 1996).

DISCUSSION

Late Silurian to Late Devonian intrusions are abundant in all lithotectonic belts northwest of the Belleisle Fault in southern and central New Brunswick (Figs. 1, 10). In contrast, the only known plutons of this age in Ganderian belts southeast of this fault are the ca. 390 Ma Gaytons Granite and similar granite intersected at depth in several boreholes on the buried Westmorland uplift (Barr *et al.* 2007; St. Peter and Johnson 2009). Devonian megacrystic varieties like that on Canaan River occur only in the Gaytons Granite, the Magaguadavic and Jimmy Hill granites in the Saint George Batholith and the Hawkshaw Granite in the Pokiok Batholith. The Gaytons Granite is composed mainly of megacrystic quartz monzonite that yielded a Middle Devonian U–Pb (zircon) age of 390 ± 0.5 Ma (Barr *et al.* 2007), so is significantly younger than the 412.3 ± 2.6 Ma age determined for the Canaan River pluton. The host rocks of the Gaytons Granite are not exposed but the intrusion is chemically and mineralogically identical to and the same age as quartz monzonite drilled beneath Carboniferous strata south of Moncton and associated with buried anorthosite and ferromylonite of the Lower Coverdale plutonic suite (White 1996; Barr *et al.* 2007; Tesfai 2011; Miller *et al.* 2018). It is unlikely that the Canaan River pluton is related to the Middle Devonian A-type Gaytons Granite (Barr *et al.* 2007). Indeed, documentation of many tens of kms of post-Devonian movement on the Belleisle Fault (Waldron *et al.* 2015) make any links between the Gaytons and Canaan River plutons unlikely.

The Saint George Batholith west of the Belleisle Fault (McLeod 1990; Mohammadi *et al.* 2017) is divided into three main groups based on age and petrogenetic characteristics: (1) Late Silurian bimodal A-type plutons (Bocabec, Utopia, Jake Lee, Welsford and Wellington Lake); (2) Early Devonian I – and S –type felsic intrusions (Magaguadavic, Jimmy Hill, John Lee Brook and Tower Hill), and (3) a much younger suite of Late Devonian fractionated I– type intrusions (Mount Douglas and satellite plutons). The megacrystic Magaguadavic and Jimmy Hill granites are also younger than the granite on Canaan River, as they have Early Devonian (Emsian stage) U–Pb (zircon) ages of 396 ± 1 Ma (Bevier 1990) and 403 ± 2 Ma (Davis *et al.* 2004),

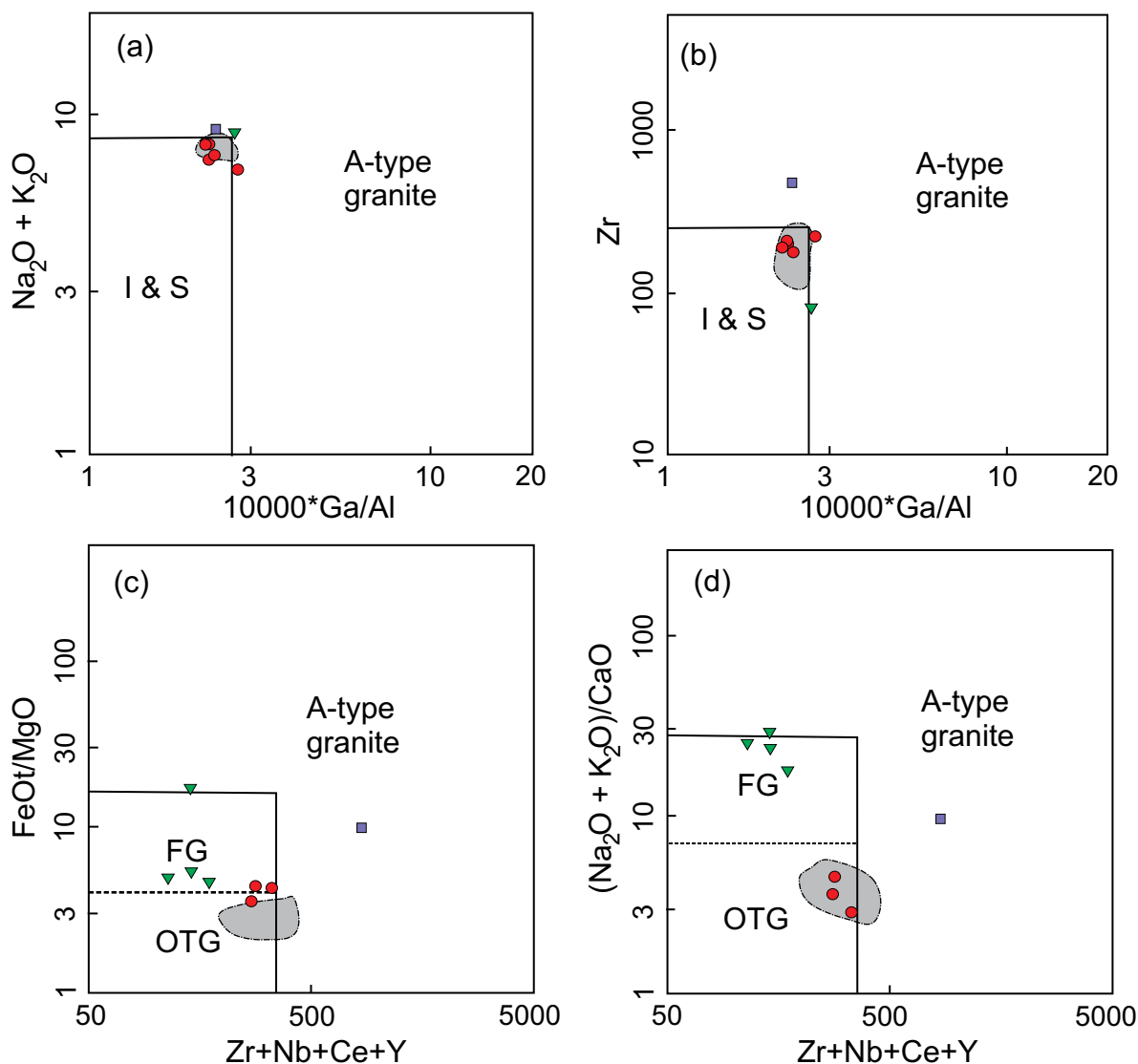


Figure 9. Plot of chemical data for the Canaan River pluton on diagrams to discriminate A-type from other granite types from Whalen *et al.* (1987). (a) $\text{Na}_2\text{O} + \text{K}_2\text{O}$ (in weight %) against Ga/Al ; (b) Zr (in ppm) against Ga/Al ; (c) FeOt/MgO against $\text{Zr} + \text{Nb} + \text{Ce} + \text{Y}$ (in ppm); (d) $(\text{Na}_2\text{O} + \text{K}_2\text{O})/\text{CaO}$ against $\text{Zr} + \text{Nb} + \text{Ce} + \text{Y}$ (in ppm). Abbreviations: FG – fractionated M-, I-, and S-type granites; OTG – unfractionated M-, I- and S-type granites.

respectively. The only granite in the Saint George Batholith similar in age to the Canaan River pluton are the garnetiferous, two-mica John Lee Brook Granite and the Wellington Lake biotite granite both of which have upper Lochkovian ages of 413.3 ± 1 Ma and 415.5 ± 2.1 , respectively (Mohammadi *et al.* 2017), however as described above they are different compositionally and geochemically than the Canaan River pluton.

The Pokiok Batholith is situated about 50 km northwest of the Saint George Batholith, on the west side of the Fredericton Fault (Venugopal 1979; McCutcheon *et al.* 1981; Lutes 1987; Whalen 1993; and Yang *et al.* 2008) (Fig. 1). The batholith intruded rocks of the Fredericton belt on its southeastern side and Cambrian to Early Ordovician rocks of the Miramichi belt (van Staal and Fyffe 1991; Fyffe 2001) along its northwestern side. All of the plutons in the Pokiok Batholith

are Early Devonian (Bevier and Whalen 1990a, 1990b; McLeod *et al.* 2003; Beal *et al.* 2010) and have chemical characteristics typical of I-type granitoids (Whalen 1993; Yang *et al.* 2008). A U–Pb (titanite) age of 411 ± 2 Ma (Bevier and Whalen 1990a, 1990b) for the Hawkshaw Granite, and a 414 ± 2 Ma (U–Pb zircon) age for related granodiorite at depth in the Lake George area (McLeod *et al.* 2003; Leonard *et al.* 2006; Lentz *et al.* 2016) indicate that the Hawkshaw Granite is the only megacrystic granite in the region known to be similar in age to the Canaan River pluton. Despite having no radiometric age control and chemical data from only one sample, Whalen *et al.* (1996) noted the lithological and geochemical similarities between the Canaan River and Hawkshaw megacrystic granites and our dating and geochemical data presented above further support a link between these two granites.

Table 2. Radiometric ages, aluminum saturation index (ASI), La/Yb and epsilon Nd values for selected Devonian granites in southern New Brunswick.

Plutonic Name	Age (Ma)	ASI	La/Yb	$\epsilon_{\text{Nd}}^{\text{(T)}}$
Gaytons	390 ± 0.5	0.94 (n = 4)	22.5 – 32.4	+0.3
Magaguadavic	396 ± 1	0.95 (n = 5)	24.3 – 29.3	+1.5
Jimmy Hill	403 ± 2	1.04 (n = 6)	20.7 – 31.2	-----
Hawkshaw	411 ± 2	1.00 (n = 12)	10.0 – 20.9	-2.5
Canaan River	412.3 ± 2.6	1.09 (n = 5)	12.3 – 17.3	-2.0
John Lee Brook	413.3 ± 2.1	1.10 (n = 4)	5.5 – 12.0	+0.2
Wellington Lake	415.5 ± 2.1	1.21 (n = 1)	10.8	-----

Geochemical and isotopic data sources: Gaytons Granite - our unpublished data, Barr *et al.* (2007) and Samson *et al.* (2000); Magaguadavic, Jimmy Hill and John Lee Brook granites - McLeod (1990) and Whalen *et al.* (1994, 1996); Hawkshaw Granite - Whalen (1993); Canaan River Granite - this study and Whalen *et al.* (1996). Wellington Lake - Mohammadi *et al.* (2017). Note: # of samples used to determine range in La/Yb values is the same as ASI, except for Canaan River pluton where N = 3 for La/Yb.

The systematic changes in isotopic and geochemical characteristics observed across the Saint George Batholith by Mohammadi *et al.* (2017) are similar to those previously observed by Whalen *et al.* (2006) across a major suture zone in central Newfoundland. This led Mohammadi *et al.* (2017) to suggest that the changes were reflecting the position of these granites relative to the Acadian suture zone. The Belleisle Fault is a major structure that separates the Silurian Kingston arc and Mascarene backarc basin that formed above a northwest-directed subduction zone beneath the trailing edge of Ganderia (Fyffe *et al.* 1999, 2011; Barr *et al.* 2002). The older parts of the Saint George Batholith were emplaced following the arrival of Avalonia during the middle Silurian onset of the Acadian orogeny (Fyffe *et al.* 1999, 2009, 2011; Barr *et al.* 2002; van Staal *et al.* 2009; Mohammadi *et al.* 2017).

Whalen *et al.* (2006) attributed the changes in La/Yb and epsilon Nd values over time in Newfoundland, to slab break-off and the transition from shallow-level melting of juvenile crust adjacent to the suture zone to deeper-level melting of old granitic basement farther away in the backarc area. Mohammadi *et al.* (2017) invoked the same model to explain the shift from older bimodal, A-type magmatism to felsic I- and S-type magmatism in the Saint George Batholith, suggesting it reflected the change from an extensional tectonic regime in the Mascarene backarc basin to a transpressional environment related to the continued convergence of the Avalonian microplate and slab-break off closer to the telescoped boundary between the Fredericton Trough, St. Croix belt, and Mascarene backarc basin (Fyffe *et al.* 2011).

The Canaan River, Hawkshaw, and John Lee Brook granites all exhibit strong negative Nb and Ti anomalies typical of arc-related rocks. However, the arc-like signature could be inherited from upper crustal source rocks as all of these

granites were emplaced into rocks of the Fredericton trough, interpreted as a foredeep basin formed during loading of the passive margin of the Tetagouche backarc basin by the overriding Brunswick subduction complex (van Staal *et al.* 2003). The signature may also be indicative of slab-breakoff during the Acadia orogeny, as postulated by Whalen *et al.* (2006).

The arrival of the leading edge of Ganderia at the Laurentian margin and subsequent inversion of the Fredericton Trough during the terminal Salinic orogeny coincided with the arrival of Avalonia at its trailing edge and the onset of the Acadian orogeny, resulting in a highly complex geodynamic setting (e.g., van Staal *et al.* 2009; van Staal and Barr 2012). The mechanism by which the Pokiok Batholith and other plutons in the Central Plutonic belt were generated has been ascribed to crustal thickening following Salinic orogenesis and/or underthrusting of Ganderia's trailing edge by the leading edge of Avalonia (van Staal *et al.* 2009; Wilson and Kamo 2016). The Early Devonian units of the Pokiok Batholith (e.g., Hawkshaw) and Saint George Batholith (e.g., John Lee Brook), as well as the Canaan River pluton (Fig. 10) were emplaced immediately after these terranes and their Silurian cover were telescoped into an area less than 150 km wide due to orthogonal shortening (Mohammadi *et al.* 2017). The current position of the Canaan River pluton suggests that the older A-type, bimodal intrusions proximal to the Acadian suture were cut out along the Belleisle and other faults in the Canaan River area by regional-scale strike slip faulting (Fig. 1).

CONCLUSIONS

The Canaan River pluton was emplaced into rocks of the

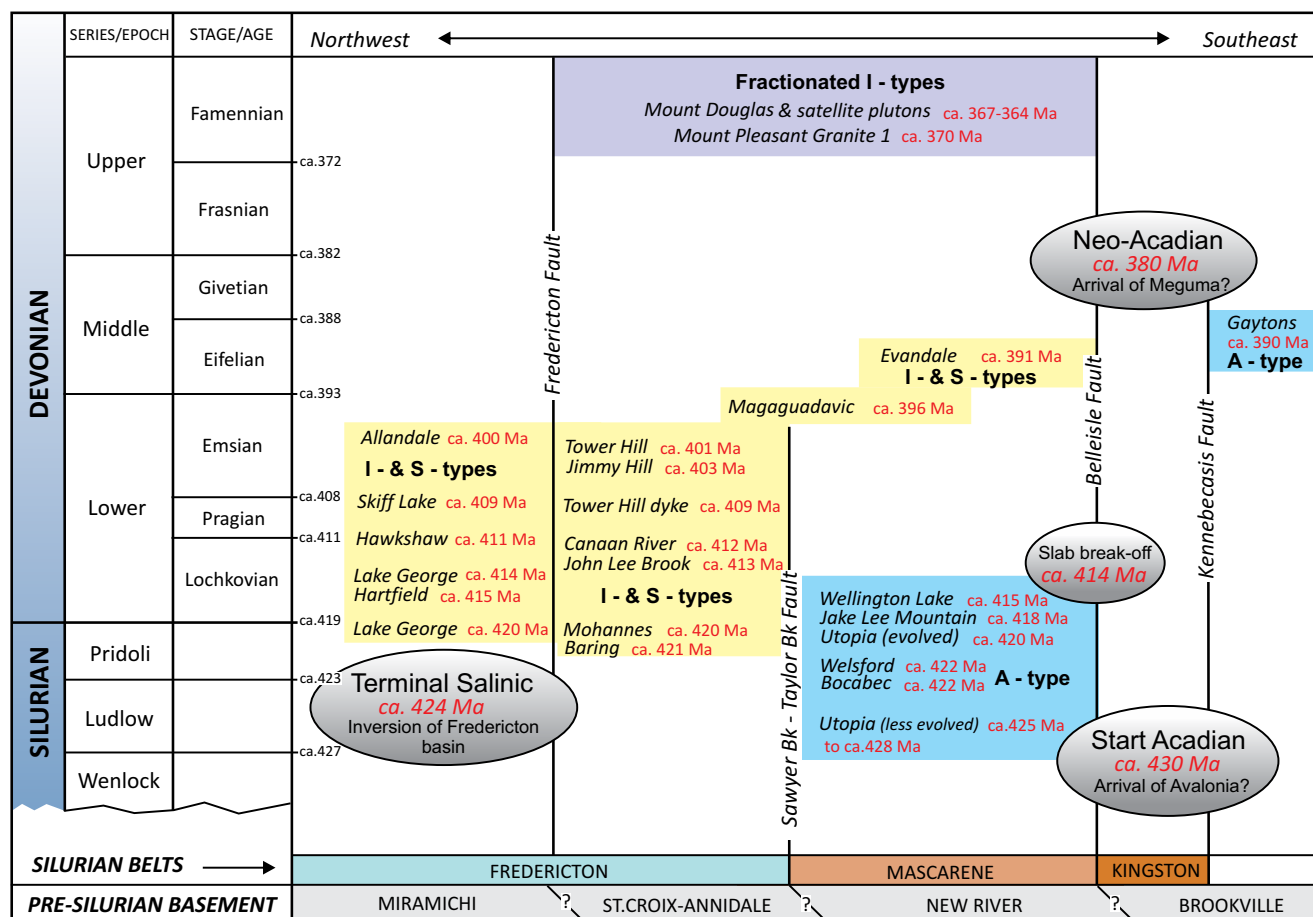


Figure 10. Panel diagram illustrating the types and ages of Late Silurian and Devonian plutonism in southern New Brunswick and their spatial and temporal relationship to major orogenic cycles. Diagram was compiled from sources cited in the text.

Fredericton trough during the Lochkovian stage of the Early Devonian. Although its current position immediately west of the Belleisle Fault appears to suggest that it is in a similar tectonostratigraphic position as the southern parts of the Saint George Batholith, the ages and isotopic and chemical characteristics of the latter intrusions are considerably different. Although the isolated location and limited exposures of the Canaan River pluton make regional correlations uncertain, its tectonostratigraphic setting, U-Pb age and geochemical data presented above indicate that the Canaan River pluton is more similar to units on the northwestern margin of the Saint George Batholith and especially the Hawkshaw Granite of the Pokiok Batholith, emplaced into sedimentary rocks of the Fredericton Trough. This interpretation indicates that the older A-type, bimodal intrusions proximal to the Acadian suture have been cut out along the Belleisle Fault in the Canaan River area by regional-scale strike slip faulting, thus explaining the termination of the Saint George Batholith and the whole Coastal Maine Magmatic Province.

The similarity of the Canaan River pluton to the Hawkshaw Granite also raises the possibility of the potential for the Canaan River pluton to host tungsten and/or intrusion-related gold - antimony mineralization, as studies on

the Lake George Antimony deposit suggest that it is related to granodiorite that has been genetically linked to the Hawkshaw phase of the batholith (Seal *et al.* 1985; Lentz *et al.* 2002; Yang *et al.* 2002, 2008; Thorne and McLeod 2003; Thorne 2005).

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Appendix. U–Pb Laser ablation-ICP-MS zircon data from the Canaan River pluton. Analyses used in calculation of the concordia age are highlighted in grey.

Sample	U (ppm)	Th (ppm)	Th/U	²⁰⁴ Pb (cps)	2σ	%Pb*	Pb- C ¹	Isotopic ratios				Calculated ages									
								²⁰⁷ Pb/ 235U	2σ	²⁰⁶ Pb/ 238U	ρ	²⁰⁷ Pb/ 206Pb	2σ	²⁰⁷ Pb/ 235U	2σ	²⁰⁶ Pb/ 206Pb	2σ	²⁰⁶ Pb/ 238U	% con		
07SJ-080-1	744	77.60	0.10430108	16.1	8.9	99.542	1	0.5295	0.0092	0.0085	0.43860	0.05819	0.0011	536.9	41.4	431.7	6.1	408.5	5.1	94.6	
07SJ-080-10	1016	161.10	0.15856299	2.6	9.9	99.885	1	0.5048	0.0070	0.0088	0.50866	0.05586	0.0009	446.8	35.8	414.8	4.7	410.3	5.3	98.9	
07SJ-080-11	1445	210.30	0.14553633	4.9	9.6	99.932	1	0.4906	0.0071	0.0082	0.54489	0.05535	0.0009	426.4	36.3	405.2	4.8	402.8	4.9	99.4	
07SJ-080-12	1040.6	117.77	0.11317509	-1.7	9.3	99.802	1	0.5017	0.0086	0.06443	0.00079	0.30281	0.05648	0.0010	471.3	39.2	412.7	5.5	402.5	4.8	97.5
07SJ-080-13	1194	192.60	0.16130653	8.8	9.7	99.856	1	0.5095	0.0074	0.06596	0.00085	0.37439	0.05614	0.0009	457.9	37.1	418	5.0	411.8	5.1	98.5
07SJ-080-14	1401	165.80	0.11834404	21	10	99.633	1	0.5285	0.0079	0.06643	0.00079	0.33405	0.05793	0.0010	527.1	37.8	430.6	5.2	414.6	4.8	96.3
07SJ-080-15	888	122.00	0.13738739	5	11	99.667	1	0.5167	0.0092	0.06513	0.00080	0.18297	0.05757	0.0012	513.4	45.8	423.3	6.1	406.7	4.9	96.1
07SJ-080-16	2813	1783.0	0.63384287	63	10	99.585	1	0.5055	0.0066	0.06317	0.00078	0.5037	0.05792	0.0009	526.7	33.7	415.6	4.4	394.8	4.7	95.0
07SJ-080-17	1062	170.90	0.16092279	21.1	9.9	99.738	1	0.5125	0.0079	0.06539	0.00080	0.32891	0.05716	0.0010	497.7	38.5	420.4	5.2	408.3	4.8	97.1
07SJ-080-18	1198	176.20	0.14707846	24	16	99.849	1	0.5066	0.0085	0.06650	0.00120	0.68785	0.05616	0.0009	458.7	35.9	417.1	5.8	415.2	7.6	99.5
07SJ-080-19	541	168.10	0.31072089	-2.4	8.9	99.796	1	0.5308	0.0100	0.06836	0.00087	0.32079	0.05638	0.0012	467.4	47.1	432.6	6.6	426.3	5.3	98.5
07SJ-080-2	704	125.80	0.17869318	15	11	99.843	1	0.5019	0.0085	0.06525	0.00081	0.23305	0.05559	0.0011	436.0	44.1	413.8	5.8	407.5	4.9	98.5
07SJ-080-20	454	129.40	0.28502203	10	10	99.666	1	0.5337	0.0100	0.06652	0.00088	0.33264	0.05778	0.0012	521.4	45.6	434.6	6.7	415.1	5.3	95.5
07SJ-080-21	919	256.00	0.27856366	41	13	99.190	1	0.5659	0.0093	0.06682	0.00088	0.06819	0.06123	0.0013	647.3	45.6	455.1	6.0	417.0	5.3	91.6
07SJ-080-22	1580	260.00	0.16455696	34	13	99.492	1	0.4980	0.0075	0.06217	0.00097	0.63952	0.05844	0.001	546.3	35.5	410.2	5.1	388.8	5.9	94.8
07SJ-080-23	1363	156.00	0.11445341	26	11	99.672	1	0.5372	0.0076	0.06761	0.00082	0.50388	0.05768	0.001	517.6	36.9	436.4	4.9	421.7	4.9	96.6
07SJ-080-24	857	119.60	0.13955659	19	10	99.832	1	0.5035	0.0089	0.06540	0.00100	0.39507	0.05597	0.0011	451.2	43.6	413.7	6.0	408.4	6.0	98.7
07SJ-080-25	670	103.90	0.15507463	38	12	99.140	1	0.5866	0.0110	0.06845	0.00090	0.29279	0.06210	0.0013	677.6	44.7	468.2	7.2	426.8	5.4	91.2
07SJ-080-26	729	60.80	0.08340192	4	11	99.908	1	0.5490	0.0120	0.07160	0.00130	0.63505	0.05579	0.0010	444.0	39.9	443.8	7.5	445.9	7.7	100.5
07SJ-080-27	1954	970.00	0.4964176	75	10	99.241	1	0.5167	0.0077	0.06192	0.00077	0.10604	0.06009	0.0011	606.8	39.6	423.3	5.0	387.3	4.7	91.5
07SJ-080-29	1148	214.00	0.18641115	8	11	99.958	1	0.4973	0.0082	0.06548	0.00081	0.12469	0.05468	0.0011	399.2	45.1	410.2	5.6	408.8	4.9	99.7
07SJ-080-3	1836	197.00	0.10729847	58	11	99.549	1	0.5376	0.0072	0.06638	0.00084	0.27825	0.05852	0.001	549.3	36.2	436.7	4.7	414.3	5.1	94.9
07SJ-080-30	710	127.30	0.17929577	11.9	9.6	99.901	1	0.5174	0.0110	0.06784	0.00095	0.60771	0.05512	0.0011	417.1	44.6	422.9	7.1	423.1	5.7	100.0
07SJ-080-31	766	68.10	0.08890339	-2.2	8.9	99.980	1	0.5255	0.0094	0.07047	0.00097	0.52545	0.05418	0.0010	378.5	41.5	429.0	6.3	439.0	5.8	102.3
07SJ-080-32	1406	183.70	0.13065434	74	15	98.933	1	0.5657	0.0097	0.06477	0.00080	0.4601	0.06305	0.0012	709.9	40.5	455.1	6.2	404.6	4.8	88.9
07SJ-080-33	910	116.20	0.12769231	8	10	99.806	1	0.5339	0.0087	0.06804	0.00096	0.40259	0.05671	0.0010	480.3	39.0	435.1	5.9	424.3	5.8	97.5
07SJ-080-34	1145	152.40	0.133100	5.5	9.1	99.964	1	0.4925	0.0077	0.06548	0.00086	0.53926	0.05436	0.0009	386.0	38.4	406.9	5.1	408.8	5.2	100.5
07SJ-080-35	378	156.10	0.41296296	7	10	99.868	1	0.5120	0.0110	0.06706	0.00090	0.07041	0.05550	0.0014	432.4	56.2	421.8	7.5	418.4	5.4	99.2
07SJ-080-36	405.8	193.10	0.475850	16	11	99.730	1	0.5270	0.0100	0.06667	0.00089	0.22531	0.05709	0.0012	495.0	46.3	429.3	6.9	416.1	5.4	96.9
07SJ-080-37	1208	149.50	0.12375828	-3.6	8.9	99.911	1	0.4926	0.0072	0.06469	0.00078	0.27845	0.05476	0.001	402.4	38.9	406.5	4.9	404.0	4.7	99.4
07SJ-080-4	2008	372.00	0.18525896	46	11	99.438	1	0.4704	0.0070	0.05852	0.00071	0.48858	0.05805	0.001	531.6	35.8	391.7	4.9	366.6	4.3	93.6
07SJ-080-5	1327	283.00	0.213263	37	12	99.389	1	0.5196	0.0085	0.06351	0.00082	0.73633	0.05922	0.0010	575.2	36.7	424.7	5.7	396.9	5.0	93.5
07SJ-080-6	886	170.00	0.19187359	23	11	99.675	1	0.5205	0.0088	0.06576	0.00082	0.24499	0.05704	0.0011	493.1	42.5	425.3	5.9	410.6	5.0	96.5

Appendix. Continued.

Sample	U (ppm)	Th (ppm)	Th/U	²⁰⁴ Pb (cps)	2σ	%Pb*	Pb- C ¹	Isotopic ratios				Calculated ages									
								²⁰⁷ Pb/ ²³⁵ U	2σ	²⁰⁶ Pb/ ²³⁸ U	2σ	ρ	²⁰⁷ Pb/ ²⁰⁶ Pb	2σ	²⁰⁷ Pb/ ²³⁵ U	2σ	²⁰⁶ Pb/ ²³⁸ U	% con			
07SJ-080-7	644	235.00	0.36490683	36	10	99.320	1	0.5410	0.0110	0.06632	0.00096	0.41816	0.06011	0.0013	607.5	46.8	438.7	7.5	413.9	5.8	94.3
07SJ-080-8	1547	170.80	0.11040724	27	10	99.617	1	0.5095	0.0082	0.06431	0.00082	0.36611	0.05772	0.0010	519.1	38.0	417.9	5.5	401.8	5.0	96.1
07SJ-080-9	1429	121.90	0.08530441	24	11	99.691	1	0.5434	0.0079	0.06813	0.00082	0.19652	0.05751	0.0010	511.1	38.2	441.0	5.2	424.9	5.0	96.3
07SJ-080-28	289.1	117.80	0.40747146	17	10	100.13	1	0.0668	0.0042	0.01035	0.00019	0.08288	0.0458	0.003	-12.9	158.3	65.4	4.0	66.4	1.2	101.5
Reference Materials																					
FC-1 - 1	202	58.35	0.28886139	5	11	99.863	1	1.947	0.0300	0.18510	0.0023	0.24450	0.07615	0.0014	1099.0	36.8	1098.5	11.0	1094.6	12	99.6
FC-1 - 2	160.91	70.63	0.43894102	15.9	9.6	99.954	1	1.966	0.0330	0.18730	0.0023	0.19319	0.07620	0.0015	1100.3	39.4	1103.9	11.0	1106.9	13	100.3
FC-1 - 3	429	304.30	0.70932401	12	12	99.972	1	1.949	0.0260	0.18586	0.0023	0.46608	0.07614	0.0012	1098.8	31.5	1097.7	9.1	1098.9	12	100.1
FC-1 - 5	285.5	177.80	0.62276708	16.8	9	99.933	1	1.956	0.0300	0.18518	0.0022	0.38946	0.07631	0.0013	1103.2	34.1	1100.4	10.0	1095.1	12	99.5
FC-1 - 6	335.8	194.10	0.57802263	10	11	99.944	1	1.945	0.0270	0.18624	0.0022	0.38211	0.07599	0.0012	1094.8	31.6	1096.3	9.3	1100.9	12	100.4
FC-1 - 7	217.8	102.72	0.47162534	6	11	99.969	1	1.956	0.0310	0.18580	0.0024	0.42121	0.07618	0.0014	1099.8	36.8	1099.7	11.0	1098.3	13	99.9
FC-1 - 8	105.3	33.13	0.31462488	-3.3	8.7	99.875	1	1.955	0.0400	0.18520	0.0024	0.19263	0.07660	0.0018	1110.8	46.9	1100.0	14.0	1095.4	13	99.6
FC-1 - 9	289.6	143.42	0.49523481	6	11	99.914	1	1.957	0.0280	0.18700	0.0023	0.19674	0.07595	0.0013	1093.8	34.3	1100.3	9.6	1105.3	13	100.5
FC-1 - 10	275.2	166.60	0.60537791	14	12	99.91	1	1.935	0.0320	0.18410	0.0023	0.02775	0.07640	0.0015	1105.6	39.2	1092.6	11.0	1089.5	13	99.7
FC-1 - 11	469.9	312.70	0.66546074	9.6	9.4	99.968	1	1.956	0.0260	0.18677	0.0022	0.29226	0.07611	0.0012	1098.0	31.6	1100.1	9.0	1103.8	12	100.3
FC-1 - 12	205.1	121.42	0.5920039	1.4	9.6	99.934	1	1.953	0.0330	0.18520	0.0024	0.26785	0.07637	0.0014	1104.8	36.6	1099.6	11.0	1095.5	13	99.6
FC-1 - 13	325.1	213.40	0.65641341	4.8	9.8	99.975	1	1.956	0.0290	0.18644	0.0022	0.42048	0.07604	0.0013	1096.1	34.2	1099.7	10.0	1102.0	12	100.2
FC-1 - 14	189.93	80.65	0.424630	24	11	99.927	1	1.940	0.0300	0.18550	0.0024	0.38374	0.07614	0.0014	1098.8	36.8	1094.2	10.0	1097.5	13	100.3
FC-1 - 15	181.4	81.80	0.45093716	4.8	8.2	99.904	1	1.952	0.0340	0.18500	0.0023	0.21203	0.07600	0.0015	1095.1	39.5	1098.0	12.0	1094.2	13	99.7
FC-1 - 16	168.3	71.70	0.42602496	14.1	8.5	99.847	1	1.963	0.0330	0.18540	0.0025	0.24315	0.07640	0.0014	1105.6	36.6	1101.8	11.0	1096.2	13	99.5
FC-1 - 17	228.4	112.50	0.49255692	-3	11	99.947	1	1.950	0.0290	0.18650	0.0023	0.11335	0.07610	0.0014	1097.7	36.8	1098.6	9.8	1103.2	12	100.4
Plesovice-1	599.3	47.21	0.07877524	6	11	99.876	1	0.4026	0.0084	0.05391	0.00073	0.25537	0.05350	0.0012	350.1	50.7	343.1	6.1	338.5	4.4	98.7
Plesovice-2	664.1	66.00	0.09938262	11	13	99.948	1	0.3889	0.0071	0.05385	0.00073	0.48561	0.05206	0.0010	288.0	43.9	334.1	5.3	338.1	4.5	101.2
Plesovice-3	552.8	49.74	0.08997829	21	15	100.027	1	0.3900	0.0088	0.05389	0.00075	0.00362	0.05250	0.0013	307.2	56.4	335.2	6.5	338.4	4.6	101.0
Plesovice-4	647.1	63.40	0.09797558	5	14	99.86	1	0.3950	0.0077	0.05347	0.00072	0.08442	0.05300	0.0012	328.8	51.4	337.7	5.7	335.8	4.4	99.4
Plesovice-5	2775	368.80	0.1329009	1	12	99.881	1	0.4018	0.0057	0.05374	0.00074	0.43045	0.05413	0.0009	376.5	35.3	342.9	4.2	337.4	4.5	98.4
Plesovice-6	905.2	94.46	0.10435263	4	10	99.932	1	0.3895	0.0076	0.05383	0.00082	0.50617	0.05242	0.0011	303.8	47.8	333.7	5.6	338.0	5.0	101.3

Notes: ¹threshold ²⁰⁴cps for no correction