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Résumé de l'article

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# U-Pb (zircon) age for the Beaver Harbour Porphyry, New River belt, southern New Brunswick, Canada

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## ABSTRACT

The Beaver Harbour Porphyry is a high-level intermediate to felsic granitoid and locally tuffaceous unit with quartz and less abundant feldspar phenocrysts. It forms a fault-bound sliver along the southern margin of the New River belt in southern New Brunswick. A concordant TIMS U-Pb (zircon) age of  $551 \pm 1.2$  Ma shows that the porphyry is of the same age as other high-level plutonic and volcanic units that form most of the New River belt. Chemical data show that these units likely formed in a volcanic-arc environment at an active continental margin. One sample from the porphyry has  $\epsilon_{\text{Nd}(t)}$  of -0.5, within the range of other samples from the New River belt and consistent with the interpretation that the belt is part of Ganderia, rather than Avalonia, which generally has more juvenile isotopic signatures.

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## RÉSUMÉ

Le porphyre de Beaver Harbour est un intermédiaire de haut niveau au granitoïde felsique et constitue une unité tuffacée par endroits comportant des phénocristaux de quartz et, moins abondamment, de feldspath. Il forme un copeau du substratum rocheux limité par les failles le long de la marge Sud de la ceinture de New River, au sud du Nouveau-Brunswick. L'âge de  $551 \pm 1,2$  Ma concordant, obtenu par datation U-Pb sur zircon à l'aide de la spectrométrie de masse à thermoionisation, indique que le porphyre a le même âge que d'autres unités plutoniques et volcaniques de haut niveau qui composent la majeure partie de la ceinture de New River. Les données chimiques indiquent que ces unités se sont probablement formées dans un environnement d'arc volcanique, dans une marge continentale active. La valeur  $\epsilon_{\text{Nd}(t)}$  d'un échantillon du porphyre est de -0,5, ce qui correspond aux valeurs des autres échantillons de la ceinture de New River et à l'interprétation selon laquelle la ceinture fait partie du terrane de Ganderia, et non de l'Avalonia, qui présente généralement des signatures isotopiques plus jeunes.

[Traduit par la rédaction]

## INTRODUCTION

Southern New Brunswick consists of fault-bounded belts or terranes (Fig. 1) with contrasts in ages and rock types (e.g., Barr *et al.* 2014). Caledonia, the belt located most outboard from the Laurentian margin, is generally considered to be part of Avalonia, whereas the other belts have been interpreted to be part of Ganderia, although the original relationships among the belts are not entirely clear (e.g., Barr

*et al.* 2014; Hibbard *et al.* 2006; Fyffe *et al.* 2009, 2011). The focus of the present study is in the New River belt, which is dominated by volcanic and plutonic rocks which have yielded diverse U-Pb (zircon) ages of ca. 630–620 Ma, 555 Ma, 540 Ma, and 515 Ma (Fig. 2). These rocks are separated from the mainly Silurian Mascarene belt to the northwest by the Back Bay Fault and from the mainly Silurian Kingstont belt to the southeast by the Belleisle Fault (Figs. 1, 2).

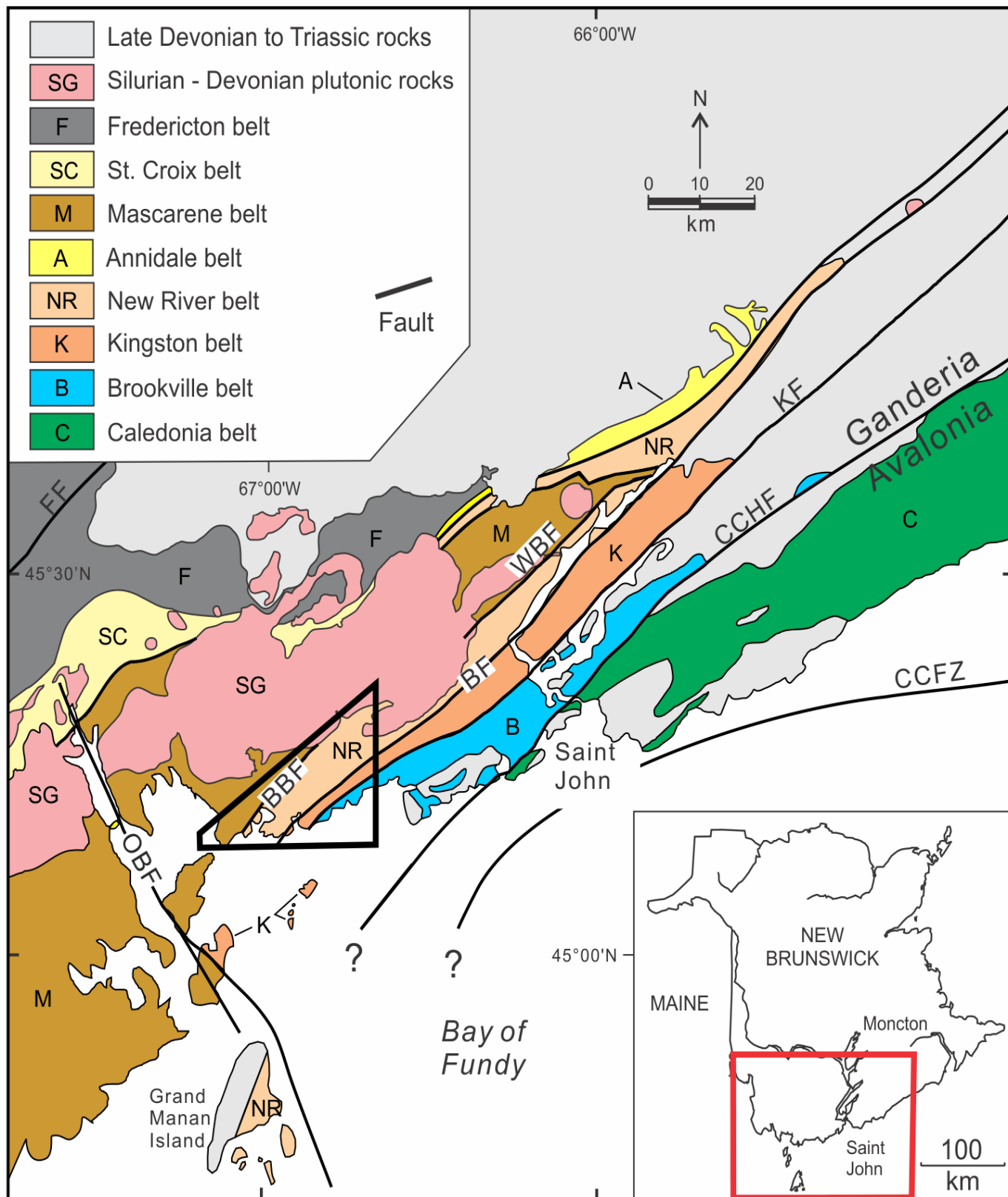
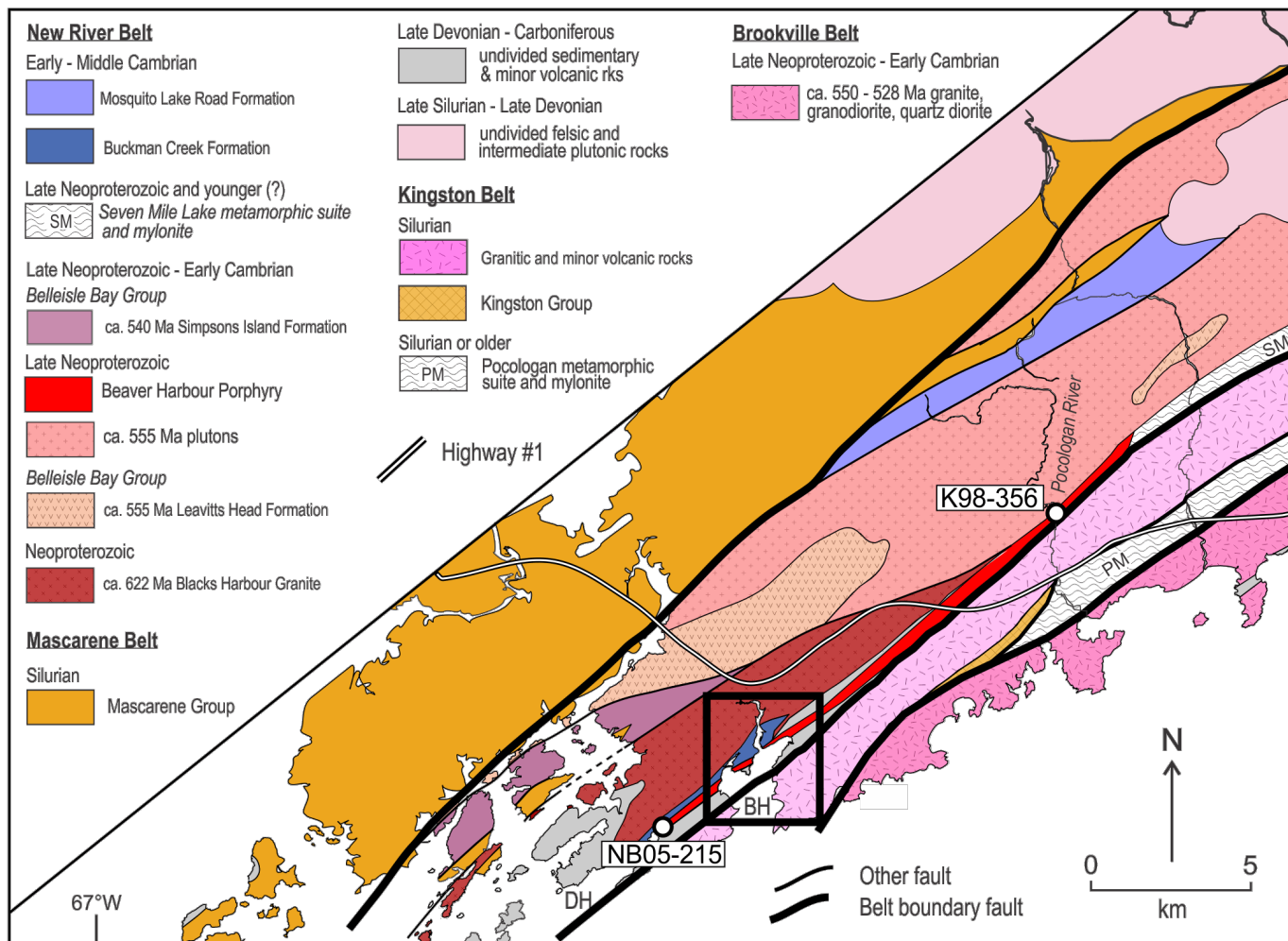


Figure 1. Geological belts or terranes in southern New Brunswick, compiled from various sources cited in the text. The area of the map in Figure 2 is outlined in black. Fault abbreviations: BBF, Back Bay Fault; BF, Belleisle Fault; CCFZ, Cobequid-Chedabucto Fault Zone; CCHF, Caledonia-Clover Hill Fault; FF, Fredericton Fault; KF, Kennebecasis Fault; OBF, Oak Bay Fault; WBF, Wheaton Brook Fault. Inset map shows the approximate map area (rectangle) shown on Figure 1 superimposed on an outline map of New Brunswick.



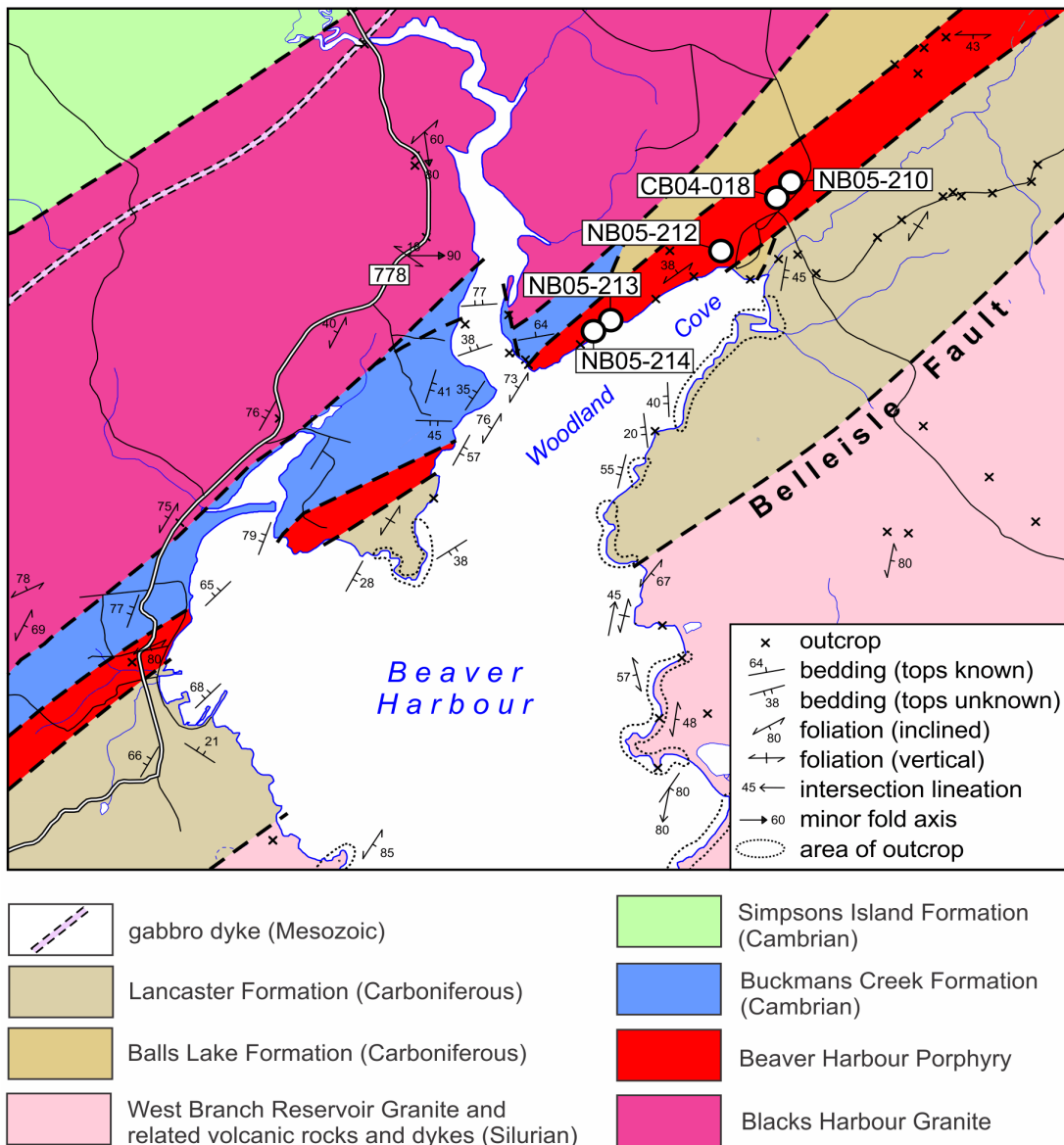
**Figure 2.** Simplified geological map of the southwestern part of the New River belt based on Bartsch (2005) and Barr *et al.* (2014). The black box indicates the area shown in Figure 3. Two sample locations are shown; the remaining sample locations are on Figure 3. Abbreviations: BH, Beaver Harbour; DH, Deadmans Harbour.

One of the mapped components in the southwestern part of the New River belt is the Beaver Harbour Porphyry (Fig. 2), also known as the Woodland Cove Porphyry (Bartsch *et al.* 2007). This unit extends along the southeastern margin of the New River belt for a distance of about 25 km but outcrop is sporadic so it may not be a continuous unit. It has a maximum width of about 1 km in Pocologan River (Fig. 2). Contacts on both sides are faults, and along most of its length it is flanked by sedimentary units assigned to the Cambrian or Carboniferous (Fig. 2). The unit is best exposed along the shore of Woodland Cove in the Beaver Harbour area. Maps of its distribution differ in detail; however, the most detailed mapping in the area was done by Bartsch (2005), who interpreted the porphyry to be in faulted contact but closely associated with the Blacks Harbour Granite. Hence, Bartsch (2005) and Bartsch and Barr (2005) considered the age of the porphyry to be ca. 620 Ma based on the published age of  $622 \pm 2$  Ma from the Blacks Harbour Granite (Barr *et al.* 2003).

The purpose of this paper to present a U-Pb (zircon) date for a sample collected from an outcrop of the Beaver Harbour Porphyry northeast of Woodland Cove (Fig. 3). The result reported here shows that the porphyry is 70 million years younger than the Blacks Harbour Granite and similar in age and chemical characteristics to the widespread ca. 555 Ma volcanic and plutonic units of the New River belt (Fig. 2). It should be noted that the age reported here, although unpublished, was used in recent papers and maps to assign a ca. 555 Ma age to the Beaver Harbour Porphyry (e.g., Fyffe *et al.* 2011; Barr *et al.* 2014).

## GEOLOGICAL SETTING

The oldest episode of magmatism known in the New River belt is represented by the Lingley and Blacks Harbour granites, which yielded early Ediacaran U-Pb zircon ages of ca. 629–625 Ma and ca. 622 Ma, respectively (Currie and McNicoll 1999; Barr *et al.* 2003). No host rocks are known



**Figure 3.** Enlarged view of the geology in the Beaver Harbour area showing the locations (black circles) of the dated sample NB05-210 and other samples for which chemical and isotopic data are listed in Tables 2 and 3. Map is modified from Bartsch *et al.* (2007).

for these plutons, which are in faulted contact with adjacent units, including the Ragged Falls Granite and comagmatic volcanic rocks, including the Leavitts Head Formation, with U-Pb (zircon) dates between ca. 555 and ca. 553 Ma (Currie and Hunt 1991; McLeod *et al.* 2003). Although contacts are mainly faults, these Late Ediacaran units are inferred to be overlain by voluminous earliest Cambrian (ca. 539 to 541 Ma) mafic and felsic pyroclastic volcanic rocks and red and green micaceous sandstone and siltstone of the Belleisle Bay Group (Johnson and Barr 2004; Johnson *et al.* 2009). In the Long Reach area the Belleisle Bay Group is overlain by fossiliferous marine sedimentary rocks that have been correlated with the Saint John Group in the Caledonia belt based

on lithological and biostratigraphic similarities (Yoon 1970; Tanoli and Pickerill 1988; Landing and Westrop 1996). In the southwestern part of the belt around Buckmans Creek, late Early Cambrian to middle Middle Cambrian fossiliferous marine sedimentary rocks are intercalated with mafic pyroclastic rocks (Helmstaedt 1968; Greenough *et al.* 1985; Landing *et al.* 2008).

In addition to the above units, the New River belt locally includes sedimentary and volcanic rocks of the Matthews Lake and Mosquito Lake Road formations. The age of the Matthews Lake Formation is bracketed by the presence of abundant ca. 539 Ma detrital zircons, likely derived from the Simpsons Island Formation of the Belleisle Bay Group

(Fyffe *et al.* 2009), and a U-Pb age of  $514 \pm 2$  Ma from a volcanic unit in the overlying Mosquito Lake Road Formation (Johnson and McLeod 1996). These volcanic rocks have been attributed to the early stages of Penobscot subduction, analogous to the ca. 513 Ma Tally Pond sequence in Newfoundland (van Staal 2007; Johnson *et al.* 2012).

The New River belt displays similarities to the Avalonian Caledonia belt (Fig. 2), in that both contain ca. 620 Ma and 555 Ma igneous suites, locally overlain by or in faulted contact with Cambrian sedimentary sequences (Currie and Hunt 1991; Currie and McNicoll 1999; Johnson and McLeod 1996; Johnson 2001; Barr *et al.* 2003, 2014; McLeod *et al.* 2003; Johnson and Barr 2004). However, Sm-Nd isotopic differences between the Neoproterozoic igneous units in New River and Caledonia terranes suggest that they have different crustal infrastructure (Samson *et al.* 2000; Barr *et al.* 2003), and the Cambrian successions differ in that those on the New River belt include volcanic rocks whereas those in Caledonia belt do not (e.g., Tanoli and Pickerill 1988). However, the significance of these differences is uncertain (e.g., Barr *et al.* 2014).

The New River belt is separated from the Caledonia belt by the Brookville and Kingston belts (Fig. 1). The Brookville belt is characterized by Neoproterozoic metasedimentary and ortho- and paragneissic rocks, as well as abundant ca. 550–528 Ma plutonic rocks and minor volcanic rocks (White and Barr 1996; White *et al.* 2002; Barr *et al.* 2014). The Kingston belt is a succession of Silurian (ca. 442–435 Ma) volcanic rocks and cogenetic high-level plutons interpreted to have formed in a continental margin volcanic arc (Barr *et al.* 2002). On the northwest, the New River belt is in faulted contact with Cambrian–Devonian volcanic and sedimentary sequences of the Mascarene and Annidale belts, and intruded by Silurian–Devonian plutons (Figs. 2, 3).

## GEOLOGY OF THE BEAVER HARBOUR AREA

As mapped by Helmstaedt (1968) and Bartsch (2005), the Beaver Harbour Porphyry occurs as faulted slivers in the Blacks Harbour Granite in the Deadmans Harbour - Beaver Harbour area, and also extends along the shoreline of Woodland Cove and along the southern margin of the belt as far as New River (Figs. 1–3). The bounding faults dip at moderate to steep angles to the northwest (Bartsch 2005). The contact between the Ragged Falls Granite and Beaver Harbour Porphyry is not exposed along Pocologan River, but is inferred to be a fault (Bartsch 2005; Bartsch *et al.* 2007). On the southeast, the porphyry unit is in inferred faulted contact with Silurian rocks of the Kingston belt in the Pocologan-New River area but farther to the southwest it is in faulted contact with an intervening package of sedimentary and minor volcanic rocks of Devonian–Carboniferous age (Fig. 3).

Near the mouth of Buckmans Creek, the porphyry is separated from the sedimentary rocks of the Cambrian Buckmans Creek Formation by a reverse dip-slip fault striking

northeast and dipping 60° southeast (Bartsch 2005). The Buckmans Creek Formation (e.g., Currie 1988) is an assemblage of fault-bounded and internally faulted sedimentary and volcanic rocks that is in places fossiliferous and has been correlated with the Saint John Group, implying a link between the New River and the Caledonia belts (e.g., Currie 1988; Tanoli and Pickerill 1988; Landing 1996; Johnson 2001; Landing *et al.* 2008). Landing *et al.* (2008) included the lower part of the Buckmans Creek Formation in the Chapel Island Formation and, apparently in error rather than intent, also included much of the Beaver Harbour Porphyry in that unit (see fig. 1b in Landing *et al.* 2008). Hence, the dated porphyry sample is from an area shown as Chapel Island Formation by Landing *et al.* (2008). Those authors also introduced the term Wades Lane Formation for the remainder of the Buckmans Creek Formation, likely an incorrect transcription of “Waites Lane” which is shown on a road sign west of Buckmans Creek. In view of these discrepancies, we follow Bartsch *et al.* (2007) and continue to use the established name Buckmans Creek Formation (Fig. 3).

The porphyry is intruded by numerous vesicular and porphyritic mafic dykes that were observed at three locations along the shore of Woodland Cove. These fine-grained dykes cross-cut the porphyry in a north-south trend and are relatively undeformed compared to the surrounding rocks. Similar dykes were observed along Buckmans Creek where they intruded the Blacks Harbour Granite. Along the northern shore of Woodland Cove, a large granitoid dyke has intruded the porphyry, and is interpreted to have been comagmatic with the host porphyry based on similar mineralogy.

## PETROLOGY

The Beaver Harbour Porphyry includes two closely associated rock types that differ in grain size and phenocryst characteristics. The most abundant rock type is quartz porphyry which consists of abundant, well-rounded, quartz phenocrysts in a dark brown aphanitic matrix. Feldspar phenocrysts are present but less abundant. Phenocrysts size ranges from 1–3 mm. The other rock type occurs mainly along the northern shore of Woodland Cove and consists of yellowish-green, anhedral feldspar phenocrysts and minor well-rounded quartz phenocrysts, in an aphanitic, dark brown to maroon groundmass. Less porphyritic brown rhyodacite which outcrops on the western shore of Beaver Harbour is also assigned to the Beaver Harbour Porphyry unit, as is similar rhyodacite which outcrops north of Deadmans Harbour, although outcrop in the intervening area is sparse (Bartsch 2005).

The brown, aphanitic groundmass in both porphyry types and the rhyodacite is composed of interlocking quartz and feldspar crystals with scattered feldspar fragments. The groundmass differs in that the quartz-feldspar porphyry consists of an equigranular mosaic of quartz and K-feld-

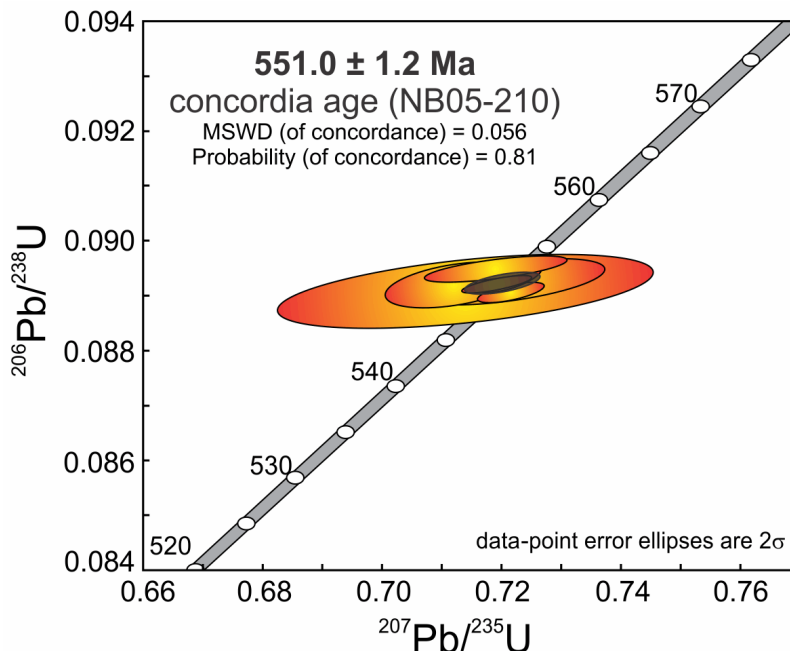


Figure 4. Concordia diagram for sample NB05-210. Analytical data are listed in Table 1.

spar, as in the rhyodacite, whereas the feldspar porphyry exhibits a very fine, microgranophyric texture. The fine mosaic texture exhibited by the quartz-feldspar porphyry and rhyodacite is indicative of the eruption of a coherent, silicic lava, whereas the microgranophyric texture may have been the result of rapid cooling of a syn-volcanic intrusion at a high level, or it may have formed from the slow cooling of a thick, densely welded ignimbrite sheet (McPhie *et al.* 1993). The presence of well-rounded quartz phenocrysts in both porphyry units suggests that they formed from the same or similar magma, with a significant amount of resorption of the quartz crystals taking place prior to eruption or intrusion.

The dated sample (NB05-210) was collected from the northern side of Woodland Cove (Fig. 3). It consists of brecciated feldspar porphyry consisting mainly of plagioclase and rare embayed quartz phenocrysts in a fine-grained granular quartzofeldspathic groundmass. Secondary minerals are abundant, including sericite, chlorite, hematite, and carbonate minerals.

#### U-PB DATA

Sample NB05-210 contained a small number of subhedral zircon grains. Seven single-grain U-Pb analyses by TIMS were conducted on grains of a variety of morphologies and sizes (Table 1). All of the analyses are concordant and overlap one another and yield a mean concordia (Ludwig 1998) age of  $551 \pm 1.2$  Ma (Fig. 4) with no sign of any inherited component. This age is similar to ages of other high-level plutonic and volcanic units that form most of the New River belt, in-

cluding the Lobster Brook Formation of the Long Reach area ( $554 \pm 6$  Ma; Johnson 2001; McLeod *et al.* 2003), the Leavitts Head Formation ( $554 \pm 3$  Ma; McLeod *et al.* 2003), and the Ragged Falls Granite ( $555 \pm 10$  Ma, Currie and Hunt 1991;  $553 \pm 2$  Ma, McLeod *et al.* 2003).

#### CHEMICAL AND ISOTOPIC DATA

The seven samples analyzed from the Beaver Harbour Porphyry display a range in  $\text{SiO}_2$  from about 60% to over 80% (Fig. 5). Data are quite scattered but generally high in Fe relative to Mg and hence ferroan in the terminology of Frost *et al.* (2001). They have lower  $\text{SiO}_2$  than the majority of felsic samples from the other ca. 555–550 Ma volcanic and plutonic rocks of the New River belt which also are mainly ferroan (Fig. 5a). The Beaver Harbour Porphyry samples are subalkaline (Fig. 5b) and display a calc-alkalic trend on the AFM diagram (Fig. 6). Although some analyses plot in the A-type granite field on Figure 5a, their trace element compositions are more characteristic of evolved I-type felsic rocks (Fig. 7a, b), formed in a volcanic-arc setting (Fig. 7c, d). They are similar to the other volcanic and plutonic rocks of the New River belt, as shown for comparison on Figures 5–7. Similarity of the REE patterns of the dated porphyry sample (NB05-210) and a volcanic sample from the Leavitts Head Formation (Fig. 8) further supports a comagmatic relationship between the ca. 555–550 Ma plutonic and volcanic rocks throughout the New River belt. These rocks were likely formed in a volcanic arc on an active continental margin late in the orogenic cycle based on their evolved compositions (Bartsch 2005; Bartsch and

**Table 1.** U-Pb thermal ionization mass spectrometry data for Beaver Harbour Porphyry sample NB05-210\*.

Sample (# grains) (a)	Compositional Parameters										Radiogenic Isotope Ratios						Isotopic Ages					
	U (ng)	Th (pg)	Pb (pg)	$^{206}\text{Pb}^*$ $\times 10^{-13}$ mol	mol % $^{206}\text{Pb}^*$	Pb* (pg)	Pb <sub>c</sub> (pg)	$\frac{^{206}\text{Pb}}{^{204}\text{Pb}}$ (e)	$\frac{^{206}\text{Pb}}{^{206}\text{Pb}}$ (f)	$\frac{^{207}\text{Pb}}{^{206}\text{Pb}}$ (f)	% err (g)	$\frac{^{207}\text{Pb}}{^{235}\text{U}}$ (f)	% err (g)	$\frac{^{206}\text{Pb}}{^{238}\text{U}}$ (f)	% err (g)	corr. coef.	$\frac{^{207}\text{Pb}}{^{206}\text{Pb}}$ (h)	$\frac{^{207}\text{Pb}}{^{235}\text{U}}$ (h)	$\frac{^{206}\text{Pb}}{^{238}\text{U}}$ (h)	$\pm$ (g)	$\pm$ (g)	$\pm$ (g)
(Z3) zircon 1	0.035	0.884	4.9	0.196	89.0%	2.7	1.96	169	0.274	0.058141	3.323	0.714155	3.595	0.089085	0.598	0.520	535.1	72.7	547.2	15.2	550.1	3.2
(Z4a) zircon 2	0.051	0.734	6.1	0.286	93.8%	5.0	1.51	303	0.229	0.058591	1.650	0.721070	1.831	0.089258	0.385	0.552	551.9	36.0	551.3	7.8	551.1	2.0
(Z5) zircon 3	0.097	0.641	11.1	0.541	94.2%	5.2	2.70	321	0.199	0.058283	1.217	0.719124	1.357	0.089487	0.224	0.676	540.4	26.6	550.1	5.8	552.5	1.2
(Z2) zircon 4	0.270	0.801	32.3	1.003	94.0%	5.1	5.30	304	0.248	0.057907	1.203	0.712101	1.327	0.089189	0.379	0.453	526.2	26.4	546.0	5.6	550.7	2.0
(Z4b) zircon 5	0.365	0.575	37.1	1.361	97.9%	14.9	2.33	900	0.179	0.058544	0.515	0.721038	0.631	0.089325	0.240	0.628	550.2	11.2	551.3	2.7	551.5	1.3
(Z6) zircon 6	0.379	0.590	39.5	1.411	97.2%	10.7	3.37	652	0.184	0.058464	0.556	0.719137	0.652	0.089211	0.145	0.724	547.2	12.1	550.2	2.8	550.9	0.8
(Z7) zircon 7	0.310	0.624	32.1	1.151	97.6%	12.9	2.31	773	0.195	0.058763	0.546	0.721552	0.635	0.089056	0.162	0.639	558.3	11.9	551.6	2.7	550.0	0.9

\*UTM, GridZone 19T, NAD83: 680149E, 4995268N

(a) Z1, Z2 etc. are internal laboratory labels for fractions composed of single zircon grain aliquots; all fractions were annealed and chemically abraded after Mattinson (2005).

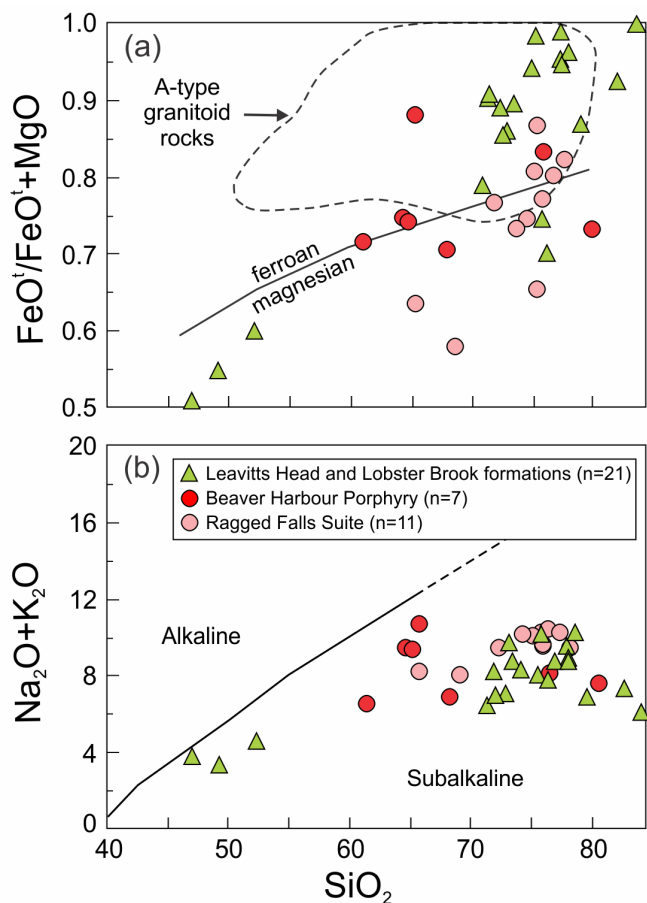
(b) U and total Pb content of zircon remnants after chemical abrasion.

(c) Model Th/U ratio calculated from radiogenic  $^{206}\text{Pb}/^{206}\text{Pb}$  ratio and  $^{207}\text{Pb}/^{235}\text{U}$  age.(d) Pb\* and Pb<sub>c</sub> represent radiogenic and common Pb, respectively; mol %  $^{206}\text{Pb}^*$  with respect to radiogenic, blank and initial common Pb.

(e) Measured ratio corrected for spike and fractionation only.

(f) Daly Pb analyses corrected for 0.22%/AMU mass bias based on repeat analysis of NBS-981. Faraday U analyses corrected for mass bias based on measured  $^{233}\text{U}/^{235}\text{U}$  ratio.(g) Corrected for fractionation, spike, and common Pb; up to 1 pg of common Pb was assumed to be procedural blank.  $^{206}\text{Pb}/^{204}\text{Pb} = 18.66 \pm 0.60\%$ ;  $^{207}\text{Pb}/^{206}\text{Pb} = 15.54 \pm 0.25\%$ ;(h) Calculate ages are based on the decay constants of Jaffey *et al.* (1971).



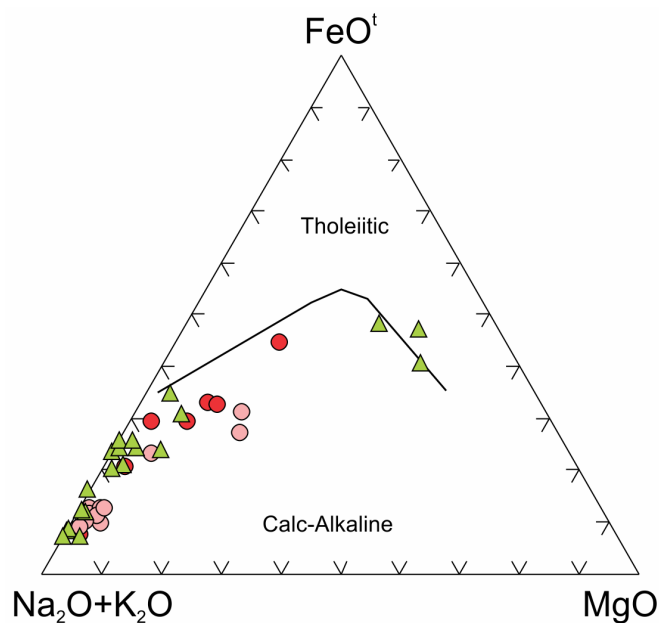


**Figure 5.** Chemical diagrams comparing samples from the Beaver Harbour Porphyry (data in Table 2) to other ca. 555–550 Ma units in the New River belt using data from Barsch (2005) and Johnson and Barr (2004). (a)  $\text{FeO}^t/(\text{FeO}^t+\text{MgO})$  against  $\text{SiO}_2$  with A-type granite field and ferroan-magnesian dividing line from Frost *et al.* (2001). (b)  $\text{Na}_2\text{O}+\text{K}_2\text{O}$  against  $\text{SiO}_2$  with alkaline/subalkaline dividing line from Irvine and Baragar (1971).

Barr 2005). This interpretation contrasts with that of Johnson and Barr (2004), who suggested a within-plate (anorogenic) setting based on a more limited data set.

According to the tectonic model of Bartsch (2005), the ca. 625–620 Ma and ca. 555–550 Ma rocks in the southern part of the New River belt, formed in two separate and unrelated subduction zones, juxtaposed as late as the Devonian, when the Perry Formation was deposited.

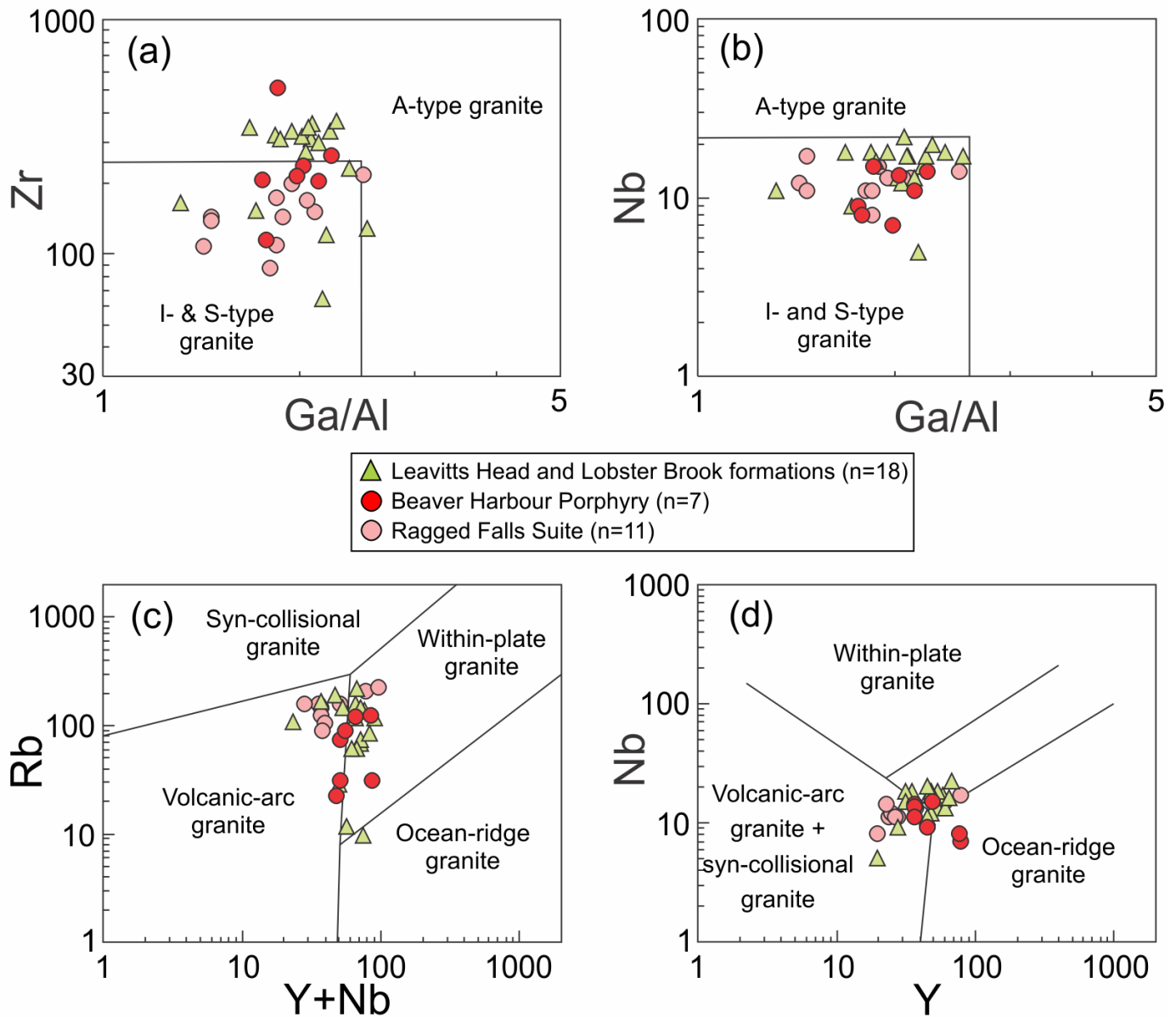
Based on bimodality of rock types and chemical composition, the ca. 560–550 Ma volcanic and plutonic rocks of the Caledonia belt have been attributed to an extensional setting (e.g., Barr and White 1999; Barr *et al.* 2003), in contrast to the arc setting suggested here for the ca. 555–550 Ma suite in the New River belt. As pointed out by Barr *et al.* (2003) and Bartsch (2005), both the ca. 620 Ma and ca. 555–550 Ma suites in the New River belt differ from units



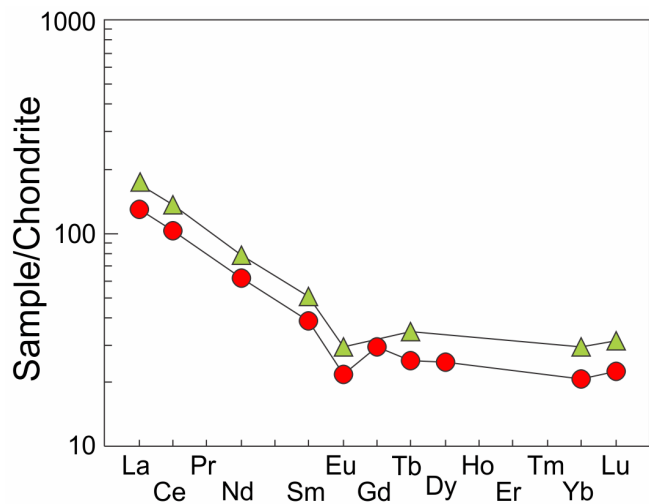
**Figure 6.** AFM diagram with the tholeiitic/calc-alkalic dividing line from Irvine and Baragar (1971). Symbols are as in Figure 5.

of corresponding ages in the Caledonia belt in their overall lithological assemblages, in particular the absence of sedimentary rocks in the New River belt. However, the significance of these differences remains difficult to assess (Barr *et al.* 2014). The age and tectonic setting for the ca. 555–550 Ma volcanic and plutonic rocks of the New River belt, including the Beaver Harbour Porphyry, are consistent with the age and tectonic setting of the Dipper Harbour Formation and associated subduction-related plutonic rocks of the Brookville belt, suggesting the possibility that they may be related, even though they are now separated by the Silurian Kingston arc belt (Barr *et al.* 2002).

The  $\epsilon_{\text{Nd}(t)}$  value for the dated sample from the Beaver Harbour Porphyry is slightly negative at -0.5 (Table 3; Fig. 9). Data from three other samples from the New River belt range from -3.7 for a sample from the Simpsons Island Formation to +1.5 for a sample from the Pull and Be Damned Granite, another component of the New River Plutonic Suite (Table 3; Fig. 9). A sample from the Blacks Harbour Granite has  $\epsilon_{\text{Nd}(622)}$  of 0.4, more juvenile than a previous reported value of -3.13 from the same unit (Barr *et al.* 2003). Combined with other previously published data (Fig. 9), the range of  $\epsilon_{\text{Nd}(t)}$  from the New River belt generally support the previous interpretation (Barr *et al.* 2003) that the underlying crust differs from that under Caledonia, from which  $\epsilon_{\text{Nd}(t)}$  results are generally more juvenile, although the data overlap (Fig. 9). The overall range of  $\epsilon_{\text{Nd}(t)}$  data is similar between the New River and Brookville belts, supporting the idea that both are part of Ganderia.



**Figure 7.** Granitoid discrimination diagrams. (a) Zr against Ga/Al. (b) Nb against Ga/Al. (c) Rb against Y+Nb. (d) Nb against Y. Fields in (a) and (b) are after Whalen *et al.* (1987); fields in (c) and (d) are after Pearce *et al.* (1984). Symbols are as in Figure 5.



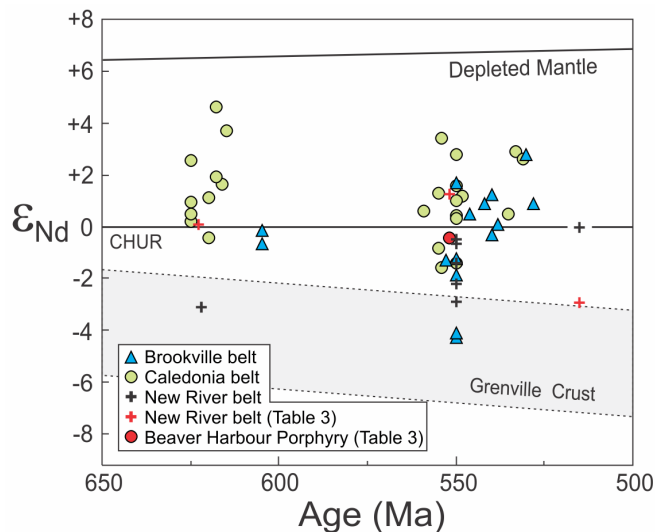
**Figure 8.** Plot of chondrite-normalized rare-earth element data for sample NB05-210 from the Beaver Harbour Porphyry (red circles) and a sample from the Leavitts Head Formation (triangles; data from Johnson and McLeod 1996). Chondrite-normalizing values are from Sun and McDonough (1989).

## CONCLUSIONS

The Beaver Harbour Porphyry was previously interpreted to be similar in age to the ca. 620 Ma Blacks Harbour Granite based on their close geographic association and chemical similarities (e.g., Bartsch 2005). However, the U-Pb (zircon) age of  $551 \pm 1.2$  Ma presented here shows that the porphyry is much younger and of the same age as other high-level plutonic and volcanic units that form most of the New River belt. Because both the ca. 620 Ma plutons and ca. 555–550 Ma plutonic and volcanic rocks of the New River belt formed in the same tectonic setting, distinguishing them on the basis of chemical characteristics, including isotopes, appears not to be reliable.

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**Figure 9.** Epsilon Nd value for sample CB04-018 and other units (data in Table 3) compared to data from the New River and Caledonia belt from the compilations of Samson *et al.* (2000) and Barr *et al.* (2003).

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