Age and petrology of the Machias Seal Island quartz monzodiorite, the southernmost rocks in New Brunswick, Canada

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ABSTRACT

Machias Seal Island in the northern Gulf of Maine consists of fine- to medium-grained weakly foliated quartz monzodiorite. Although previously inferred to be as young as Devonian, the quartz monzodiorite yielded an Ediacaran–Early Cambrian U-Pb (zircon) age of 542.0 ± 0.9 Ma. Typical Machias Seal Island quartz monzodiorite contains strongly zoned plagioclase (50%), about 30% mafic minerals (biotite and amphibole with relict cores of both ortho- and clinopyroxene, and 20% interstitial quartz and orthoclase. The average chemical composition (5 samples) has 60.6% SiO_2, with relatively high Al_2O_3 (over 16%) and low K_2O (2.8%). Overall, the chemical characteristics, including low Rb, Y, and Nb, are consistent with emplacement in a continental margin subduction zone. The quartz monzodiorite contains abundant ovoid metadioritic enclaves, likely of cognate origin. Age and compositional similarities strongly suggest correlation of Machias Seal Island quartz monzodiorite with the abundant ca. 550–525 Ma gabbroic to granitic plutons of the Brookville terrane on the mainland of southern New Brunswick. Its age is similar also to the ages of volcanic and some plutonic rocks on Grand Manan Island and in the New River terrane in mainland southern New Brunswick, strengthening the interpretation that all of these areas are part of Ganderia. Hence the Fundy Fault southeast of Machias Seal Island likely marks the boundary between Ganderia and Avalonia in the Gulf of Maine.

RÉSUMÉ

L'île Machias Seal, dans la partie nord du golfe du Maine, se compose de monzodiorite quartzique à grains fins à moyens faiblement feuilletée. Même si on déjà présumé que son origine remonterait au Dévonien, une datation de la monzodiorite quartzique par la méthode U-Pb sur zircon a indiqué un âge d'Ediacara et du début du Cambrien, soit de 542,0 ± 0,9 Ma. Les minéralisations caractéristiques de monzodiorite quartzique de l'île Machias Seal renferment un plagioclase fortement zoné (50 p. 100), environ 30 p. 100 de minéraux mafiques (biotite et amphibole accompagnées de noyaux résiduels d'orthopyroxène et de clinopyroxène), ainsi que 20 p. 100 de quartz et d'orthoclase interstitiels. La composition chimique moyenne (5 échantillons) est de 60,6 p. 100 de SiO_2, une teneur relativement élevée de Al_2O_3 (plus de 16 p. 100) et une faible teneur en K_2O (2,8 p. 100). Dans l'ensemble, les caractéristiques chimiques de ces minéralisations, y compris la faible teneur en Rb, Y et Nb, sont généralement associées à un emplacement dans une zone de subduction de la marge continentale. La monzodiorite quartzique contient d'abondantes quantités d'enclaves de métadiorite ovoïdes, vraisemblablement de la même origine. L'âge et les similitudes de composition de ces roches portent à croire qu'une corrélation pourrait s'établir entre la monzodiorite quartzique de l'île Machias Seal et la grande quantité de plutons gabbroïque à granitique de 550–525 Ma observée dans le socle de Brookville, dans la partie continentale du Sud du Nouveau-Brunswick. Par ailleurs, ces roches ont le même âge que celui des roches volcaniques et de certains plutons de l'île Grand Manan et du socle de New River dans la partie continentale du Sud de la province, ce qui viendrait confirmer l'interprétation voulant que toutes ces zones fassent partie de Ganderia. La faille de Fundy au sud-est de l'île Machias Seal marque donc la limite entre Ganderia et Avalon dans le golfe du Maine.

[Traduit par la redaction]

INTRODUCTION

Machias Seal Island is located at the mouth of the Bay of Fundy, about 20 km southwest of Grand Manan Island and 30 km southeast of Machias, Maine (Fig. 1). The small rocky island is barren except for a lighthouse and dwellings maintained by the Government of Canada, although ownership of the island is disputed between Canada and the United States

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of America (e.g., Schmidt 2002). The island has the last occupied lighthouse in the Maritime Provinces, and is well known among bird-watchers as a nesting site for puffin, auk, and other seabirds. In addition to its political significance, Machias Seal Island is important geologically because of its location in an area through which it is difficult to trace terranes from Nova Scotia and New Brunswick into the New England states (Fig. 1). Geological studies on nearby Grand Manan Island (Fig. 1) have not resolved that problem, as rocks there have equivocal terrane affinity (e.g., Miller *et al*. 2007; Fyffe *et al*. 2009). However, they most resemble those of the New River terrane of southern New Brunswick, suggesting that the Ganderian Kingston and Brookville belts, as well as Avalonia and Meguma, all lie outboard of Grand Manan Island (Fig. 1).

Because of its small size, most regional geological maps (e.g., Hibbard *et al*. 2006) do not show Machias Seal Island. More detailed local maps have shown the island as Precambrian granite (e.g., Potter *et al*. 1979) or Silurian–Devonian granite (e.g., McLeod *et al*. 1994; New Brunswick Department of Natural Resources 2010). The purpose of this paper is to describe the petrology of a suite of granitoid samples collected from the island, present a new U-Pb zircon age for the suite, and use these results to interpret the most likely correlative units in the region.

GEOLOGY OF MACHIAS SEAL ISLAND

With the exception of grassy areas in the central part of the island, outcrop is continuous on Machias Seal Island (Fig. 2). The rocks are grey to locally pink, fine- to medium-grained, weakly foliated quartz monzodiorite with abundant dioritic

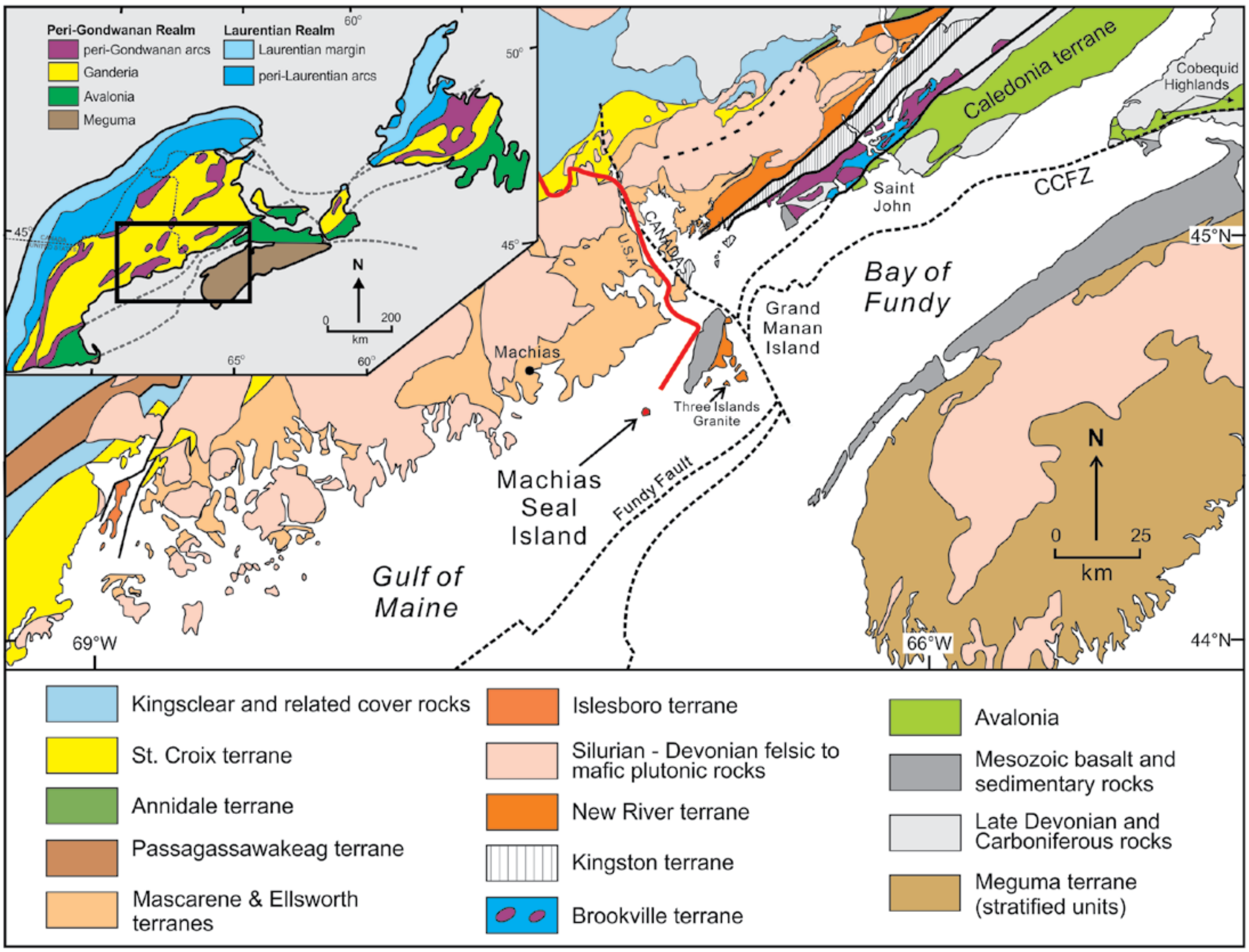

Fig. 1. Simplified geological map of the area around the Bay of Fundy and Gulf of Maine, showing the location of Machias Seal Island (modified from Hibbard *et al.* 2006). CCFZ = Cobequid-Chedabucto fault zone. The inset map shows a terrane map of the northern Appalachian orogen, also modified after Hibbard *et al.* (2006), with the approximate location of the main map indicated by a rectangle.

enclaves, generally less than 20 cm in diameter. The quartz monzodiorite is cut by two steeply dipping mafic dykes, each about 1 m in width, which trend at about 015° across the island (Fig. 2). The eastern dyke is alkalic, and contains pseudomorphs of olivine phenocrysts in a fine-grained groundmass of plagioclase, brown amphibole, and pyroxene. The other dyke is more altered and consists mainly of plagioclase, pyroxene, and their alteration products. The age of these dykes is unknown, other than being younger than the quartz monzodiorite.

Typical Machias Seal Island quartz monzodiorite contains 50% strongly zoned plagioclase, 30% mafic minerals and about 20% interstitial quartz and K-feldspar (Figs. 3a, b). Plagioclase is strongly zoned from labradorite to oligoclase, based on petrographic determinations using extinction angles and on electron microprobe analyses in 3 samples (Fig. 4a). The most abundant mafic mineral is green amphibole of magnesio-hornblende composition (Fig. 4b). The larger amphibole grains typically contain relict cores of both orthopyroxene and clinopyroxene, with the clinopyroxene rimming the orthopyroxene. The orthopyroxene is somewhat less magnesian than the coexisting clinopyroxene (Fig. 4c). Brown biotite occurs in association with amphibole and as separate grains. In both modes of occurrence, its composition is intermediate between phlogopite and annite, with relatively low aluminum content, and it plots in the field for calc-alkalic orogenic suites in the ternary MgO-FeO^t-Al_2O_3 discrimination diagram (Fig. 4d) of Abdel-Rahman (1992). Apatite, zircon (see description below), and magnetite are the most abundant accessory phases.

The enclaves are finer grained than their host rocks and of more mafic (dioritic) composition. They consist of plagioclase laths, orthopyroxene, clinopyroxene, amphibole, and biotite in a groundmass of plagioclase and K-feldspar (Figs. 3c, d). In contrast to the host monzodiorite, quartz is minor or absent in the enclaves. The compositions of the mafic minerals in the enclaves are similar to those in the host quartz monzodiorite (Fig. 4b, c, d), although the plagioclase is generally more calcic, up to An_{90} (Fig. 4a).

GEOCHRONOLOGY

A sample of quartz monzodiorite (#182) from the eastern side of the island (Fig. 2) was collected for dating at the Pacific Centre for Isotopic and Geochemical Research (PCIGR). Zircons were separated using conventional crushing, grinding and wet shaking table methods, followed by heavy liquid and magnetic separation. The sample yielded abundant zircons, comprising clear, colorless to pale yellow, stubby square prisms (length:width ratios of 1-2) with simple terminations. Some of the grains were fractured; however, no internal zoning or inherited cores were observed under a binocular microscope or in transmitted light.

Methods used for U-Pb zircon analysis using ID-TIMS techniques at the PCIGR are described by Mortensen *et al.* (1995). Individual zircon fractions for analysis comprised 1 to 11 grains. U-Pb analytical data are listed in Table A5, and

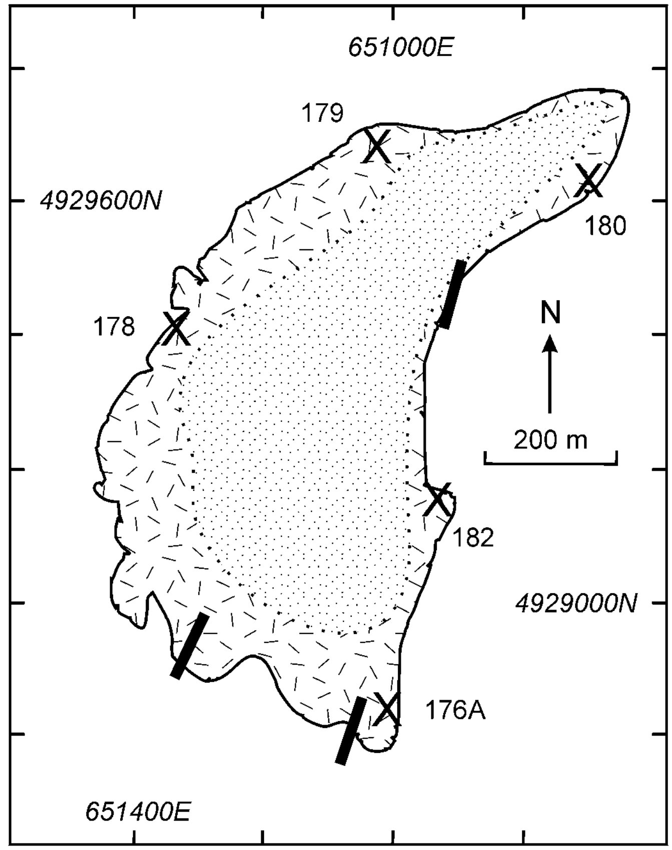

Fig. 2. Sketch map of Machias Seal Island, modified from Schmidt (2002), showing sample locations. Slash pattern indicates continuous outcrop along the shoreline. Thick dark lines are mafic dykes. Shaded area indicates mainly grass-covered central part of the island.

are shown on a conventional concordia plot in Figure 5. Four multigrain fractions of zircon (fractions B, C, D, E) were analyzed initially. The outer portions of these zircon grains had been strongly air abraded prior to dissolution in an attempt to minimize the effects of post-crystallization Pb-loss. The four analyses defined a short linear array that suggested an upper intercept age of approximately 542 Ma; however, there is significant scatter in the data and only analysis C is concordant (Fig. 5). In an attempt to obtain replicate concordant analyses and thus more confidently constrain the age of the rock, three additional zircon fractions were analyzed (B2, D2, E2). These analyses are of single zircon grains that were "chemically abraded" prior to dissolution. The chemical abrasion process involves thermally annealing the grains and then subjecting them to a strong leaching step in concentrated hydrofluoric acid; this procedure has been shown to remove most portions of zircon grains that have been altered or otherwise disturbed, and in many cases produces more concordant and reproducible analyses (see discussion of the chemical abrasion technique as used in the PCIGR in Scoates and Friedman 2008). Two analyses of the chemically abraded zircons still show minor discordance, suggesting that in those cases not all of the altered and

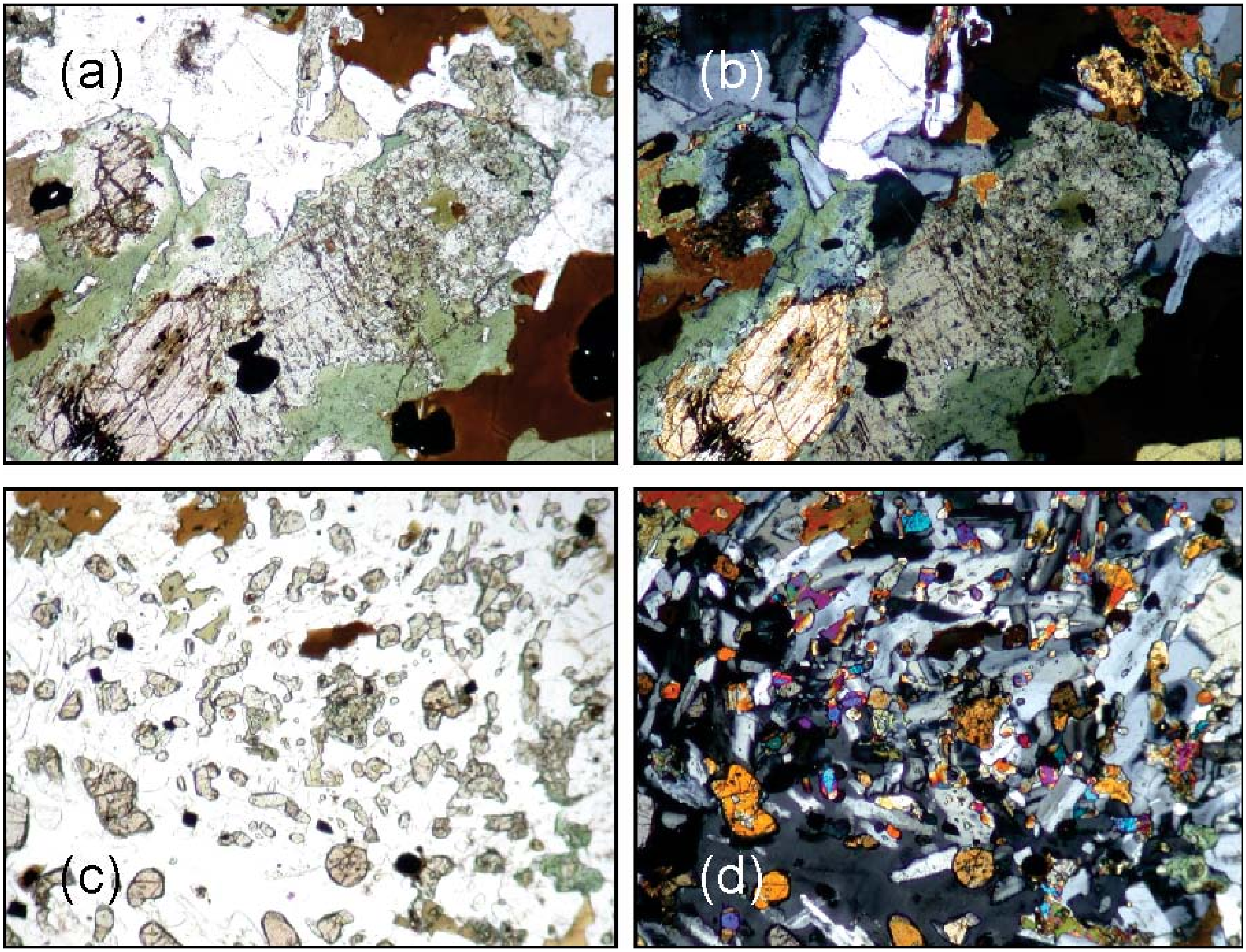

Fig. 3. (a, b) Photomicrographs of Machias Seal Island quartz monzodiorite (sample NB04-176a) in plane polarized light and under crossed polars. (c, d) Photomicrographs of enclave NB04-183a in plane polarized light and under crossed polars. Width of the field of view is about 4 mm in all photographs.

disturbed portions of the grains were removed by the process. One of the analyses (B2), however, yields a concordant analysis that completely overlaps with air-abraded fraction C (Fig. 5). A regression of all of the data gives calculated upper and lower intercept ages of 541.9 ± 3.5 Ma and -125 ± 680 Ma, respectively (MSWD = 0.61; probability of fit = 0.69). A regression of all seven analyses forced through the origin yields an upper intercept age of 542.5 ± 2.9 Ma (MSWD = 0.53; probability of fit = 0.79). We consider the best estimate for the crystallization age of the sample, however, to be given by a weighted average of $^{206}Pb/^{238}U$ ages for the two concordant analyses (C and B2), at 542.0 ± 0.9 Ma.

This age coincides closely with the Ediacaran-Cambrian boundary (Walker and Geissman 2009) and is much older than the Early Devonian age previously inferred for intrusive rocks on the island on current maps (e.g., New Brunswick Department of Natural Resources 2010). Regionally, it falls within the range of U-Pb (zircon) ages obtained from numerous plutons in the Brookville terrane of southern New Brunswick (Fig. 6; e.g., White *et al*. 2002). It is also similar to the ages of some units in the New River terrane (Fig. 6) and three units on nearby Grand Manan Island: High Duck Island Granite (547.3 ± 1.1 Ma; Miller *et al*. 2007), tuff in the Priest Cove Formation (539 ± 3.3 Ma; Miller *et al*. 2007), and the Stanley Brook granite (535 ± 2.5 Ma; P. Valverde-Vaquero, unpublished written report to L.R. Fyffe, 2003). The similarity between Grand Manan Island and the New River terrane in rock types, Sm-Nd isotopic characteristics, and ages has been used to infer a link between those two areas, and for including both of them, as well as the Brookville terrane, in Ganderia (Barr *et al*. 2003; Miller *et al*. 2007; Fyffe *et al*. 2009). As documented in detail by Barr *et al*. (2003) and also discussed in subsequent papers (e.g., Miller *et al*. 2007; Fyffe *et al*. 2009), differences in rock types and ages indicate that none of these areas is likely to be related to the Avalonian Caledonia terrane.

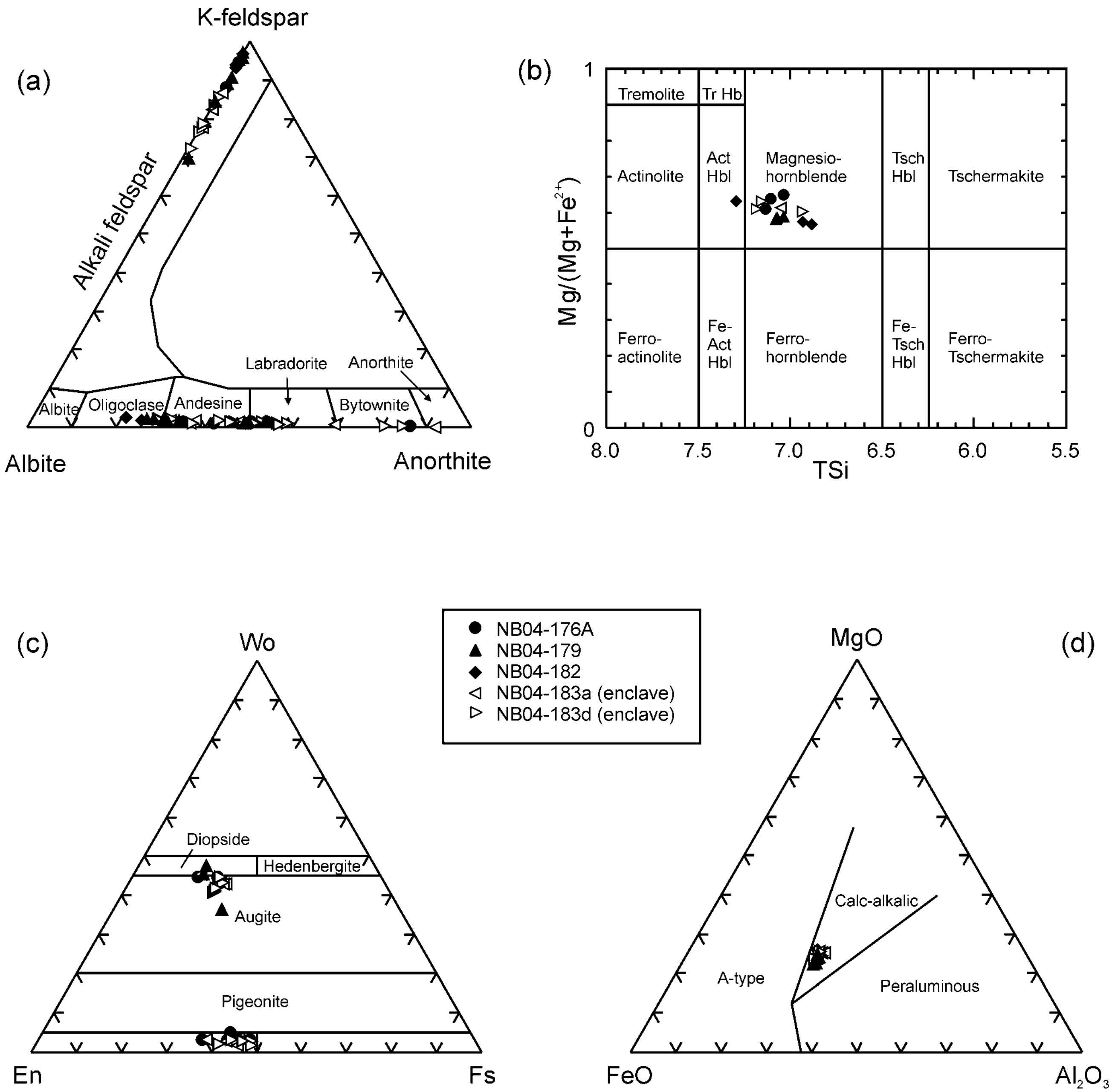

Fig. 4. Mineral compositions determined by electron microprobe. (a) Feldspar in terms of An-Ab-Or components (data from Table A1a, b). (b) Amphibole compositions in terms of tetrahedral Si and Mg/Mg+Fe^{2+} with fields from Leake *et al.* (1997) (data from Table A2). (c) Pyroxene compositions in terms of Ca-Mg-Fe end members (data from Table A3). (d) Biotite compositions plotted on the MgO-FeO-Al_2O_3 discrimination diagram of Abdel-Rahman (1992) (data from Table A4).

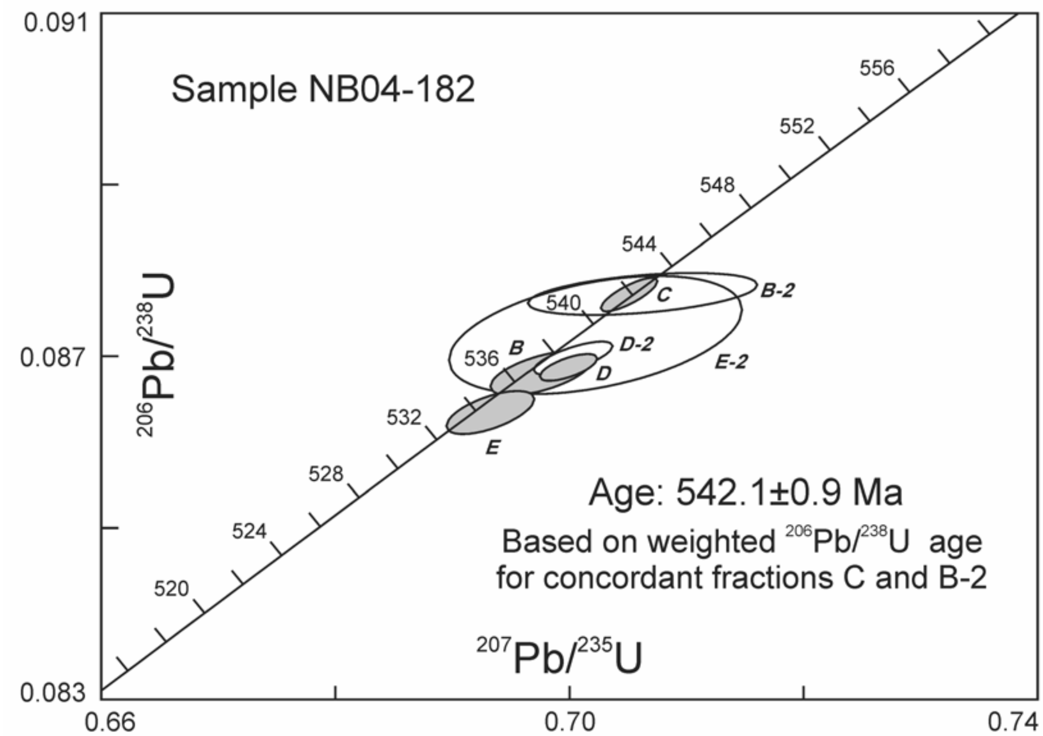

Fig. 5. U-Pb concordia plot for zircon fractions from sample NB04-182. Shaded error ellipses correspond to analyses of air-abraded zircon fractions and open ellipses represent chemically abraded analyses, as discussed in the text. Error envelopes are shown at the 2 sigma level. Data are from Table A5.

GEOCHEMISTRY

Chemical analyses were obtained for 5 samples of the Machias Seal Island quartz monzodiorite and 2 samples from its dioritic enclaves. The quartz monzodiorite samples range in SiO_2 content from 59% to 63%, whereas the enclaves have lower SiO_2 (56% and 54%) (Fig. 7). A plot of CIPW normative compositions (Fig. 8a) is consistent with the names assigned on the basis of modal estimates (diagram not shown). The enclaves and their host rocks tend to lie on linear trends in major element compositions (Fig. 7, 8b), suggesting that they are linked by crystal fractionation processes. Chondrite-normalized rare-earth element (REE) patterns are also similar in enclave samples and quartz monzodiorite sample NB04-176a, the most mafic of the analyzed quartz monzodiorite samples. The most felsic sample, NB04-182, shows higher REE, especially light REE, and a larger negative Eu anomaly consistent with feldspar fractionation (Fig. 9a). A multi-element comparison diagram also shows similarity between enclaves and host quartz monzodiorite samples, and a trend toward increasing incompatible element abundance with increasing silica content in the samples (Fig. 9b).

Because the age obtained for the quartz monzodiorite falls within the range of ages reported for Brookville terrane plutons (Fig. 6), and some of those plutons include similar monzodioritic rock types (e.g., White *et al*. 2002), fields are shown on the geochemical diagrams for those plutons (Figs. 7-9). In most cases the Machias Seal Island samples plot within the fields defined by the Brookville terrane plutons, and display similar trends, consistent with magma evolution dominated by crystal fractionation of plagioclase and mafic minerals. The REE patterns are also similar, although the Machias Seal Island enclave samples plot at the uppermost part of the range for plutons of the Brookville terrane, and the dated sample lies well above the range. The cause of this difference is not apparent in the mineralogy of the samples.

The Machias Seal Island samples have chemical features consistent with origin in a continental margin subduction zone (Fig. 10), an interpretation also made for the Brookville terrane plutons in earlier studies (White *et al*. 2002).

The epsilon Nd value of -1, calculated at 540 Ma (Table A8), is similar to that of many samples in the Brookville and New River terranes (Fig. 11). The tendency for igneous units to have negative epsilon Nd values is considered to be one of the characteristic features of Ganderia (Kerr *et al*. 1995; Samson *et al*. 2000; Barr *et al*. 2003).

REGIONAL IMPLICATIONS

The similarity in both age and petrology of the Machias Seal Island quartz monzodiorite to plutons of the Brookville

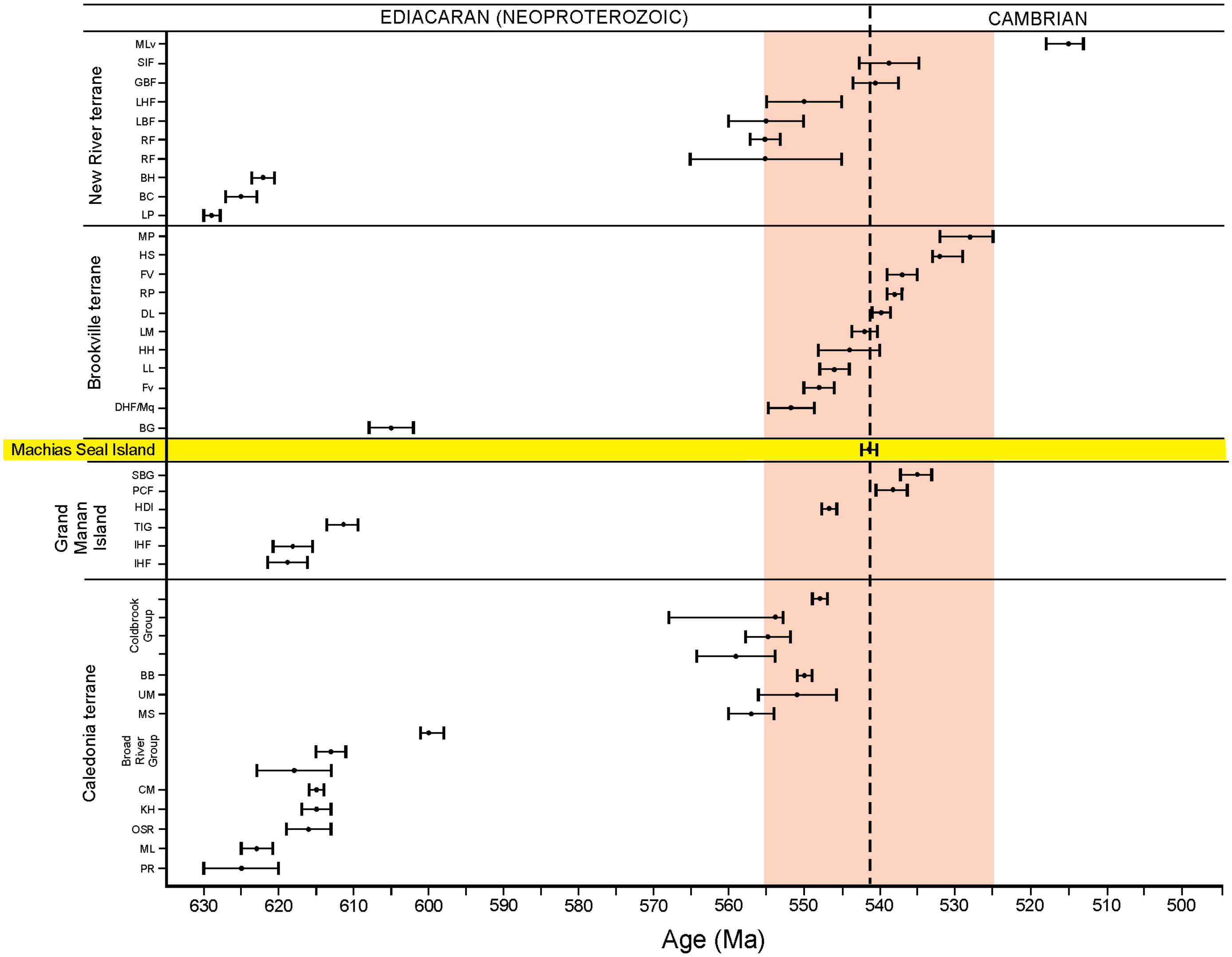

Fig. 6. Compilation of U-Pb (zircon) crystallization ages from igneous units in the Caledonia, Brookville, and New River terranes, as well as Grand Manan Island (New River terrane?), compared to the new age reported here for Machias Seal Island quartz monzodiorite (in horizontal shaded band). Vertical dashed line indicates the Ediacaran-Cambrian boundary after Walker and Geissman (2009). Vertical shaded band indicates range of ages for plutons of the Brookville terrane. Data are compiled from Currie and Hunt (1991), Bevier and Barr (1990), Bevier *et al.* (1990), Barr *et al.* (1994, 2000, 2003), White *et al.* (2002), Currie and McNicoll (1999), Johnson *et al*. (2009), and McLeod *et al.* (2003). Unit abbreviations (alphabetical): BB, Bonnell Brook Granite; BC, Brittain Creek Pluton; BG, Brookville Orthogneiss; BH, Blacks Harbour Granite; CM, Caledonia Mountain Gabbro; DHF, Dipper Harbour Formation; DL, Duck Lake Gabbro; FV, French Village Quartz Diorite; Fv, Fairville Granite; GBF, Grant Brook Formation; HDI, High Duck Island Granite; HH, Harvey Hill Granite; HS, Hanson Stream Granite; IHF, Ingalls Head Formation; KH, Kent Hills Granodiorite; LBF, Lobster Brook Formation; LHF, Leavitts Head Formation; LL, Ludgate Lake Granodiorite; LM, Lutes Mountain Quartz Diorite; LP, Lingley Pluton; ML, Millican Lakes Granodiorite; MLv, Mosquito Lake volcanics; MP, McCarthy Point Granodiorite; Mq, Musquash Harbour Pluton; MS, Mechanic Settlement Pluton; OSR, Old Shepody Road Granite; PCF, Priest Cove Formation; PR, Pollett River Granodiorite; RF, Ragged Falls Pluton; RP, Renforth Pluton; SBG, Stanley Brook Granite; SIF, Simpsons Island Formation; TIG, Three Island Granite; UM, Upham Mountain Granite.

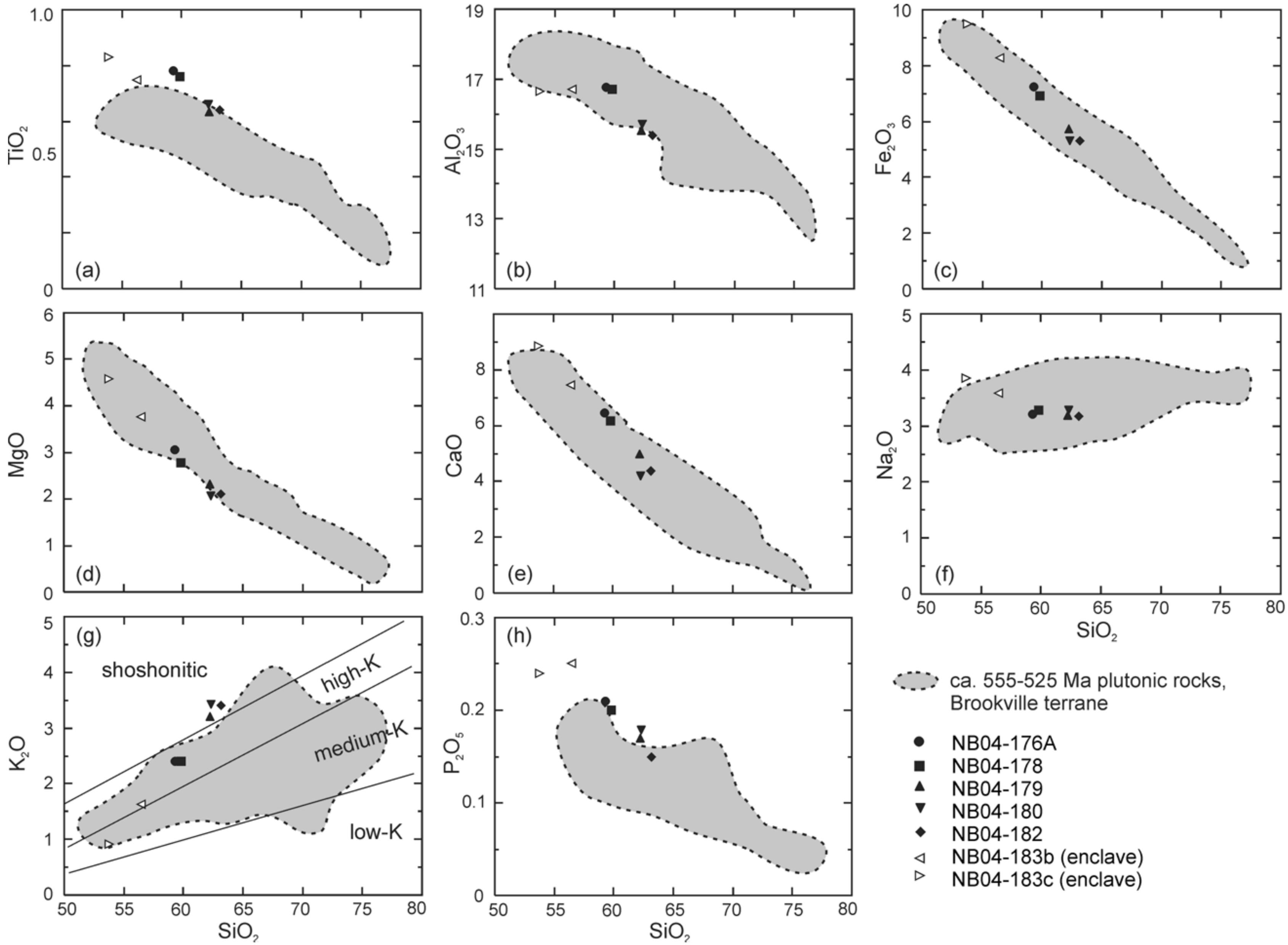

Fig. 7. Major element compositions of whole-rock samples from the Machias Seal Island quartz monzodiorite and enclaves (from Table A6) compared to the grey field for plutons in the Brookville terrane. The fields for Brookville terrane plutons are after Barr *et al.* (2003). Fe_2O_3 is total iron expressed as Fe_2O_3. Fields in (g) are after Middlemost (1975).

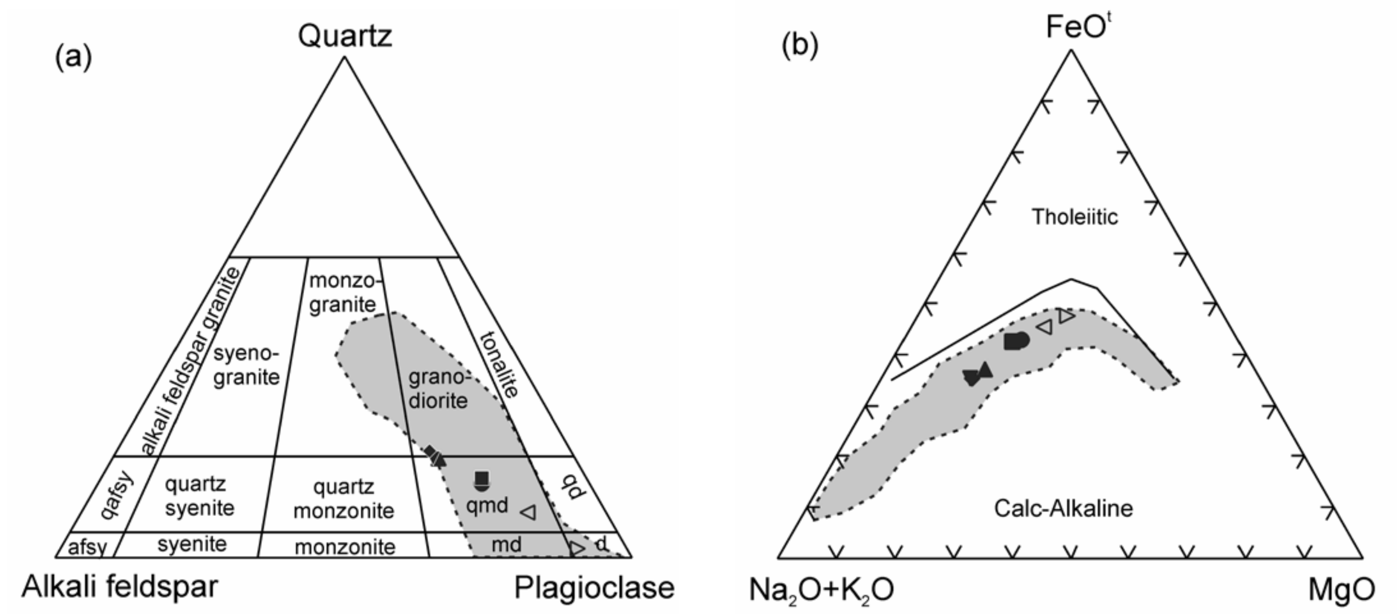

Fig. 8. (a) Calculated normative mineralogy and (b) AFM diagram for samples from the Machias Seal Island quartz monzodiorite and enclaves compared to the fields for plutons in the Brookville terrane. Symbols and fields are as in Fig. 7. Normative mineralogy was calculated with Fe_2O_3 set at 0.15 $Fe_2O_3^t$. Fields in (a) are after Streckeisen (1976). Tholeiitic/calc-alkalic dividing line in (b) is from Irvine and Baragar (1971). Abbreviations in (a) are: afsy, alkali feldspar syenite; d, diorite; m, monzo; q, quartz.

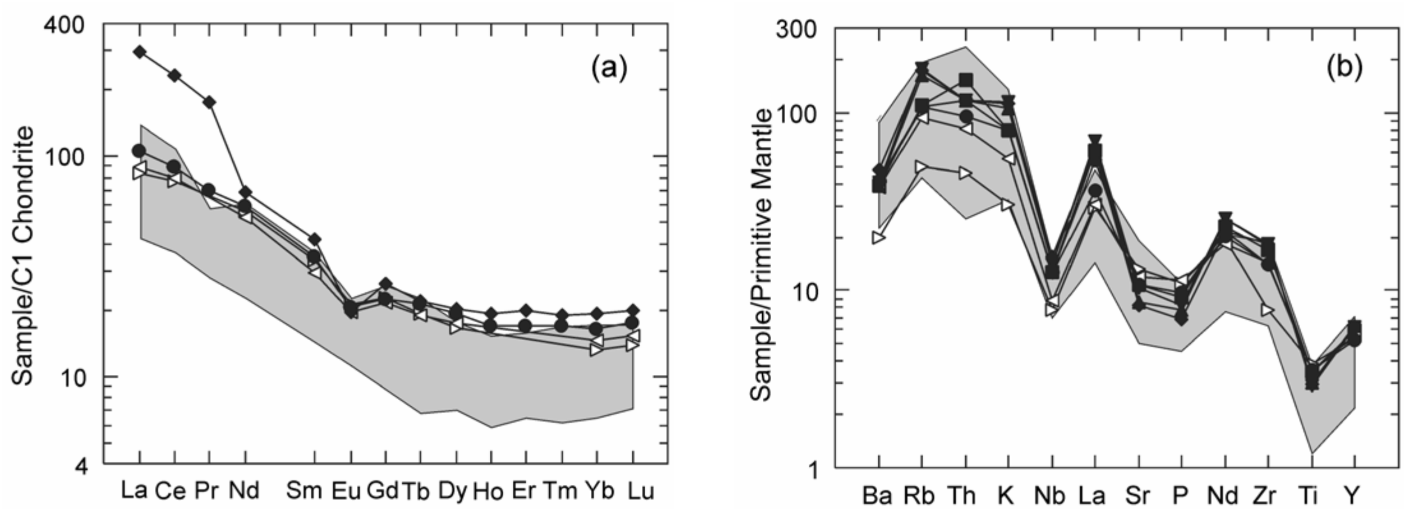

Fig. 9. (a) Plot of chondrite-normalized rare-earth element data from Table A7 for samples from the Machias Seal Island quartz monzodiorite and enclaves compared to the field (shaded) for plutons in the Brookville terrane. (b) Mantle-normalized multi-element variation diagram for samples from the Machias Seal Island quartz monzodiorite and enclaves compared to the field (shaded) for plutons in the Brookville terrane. Sample symbols are as in Fig. 7. Chondite and primitive-mantle normalizing values are from Sun and McDonough (1989).

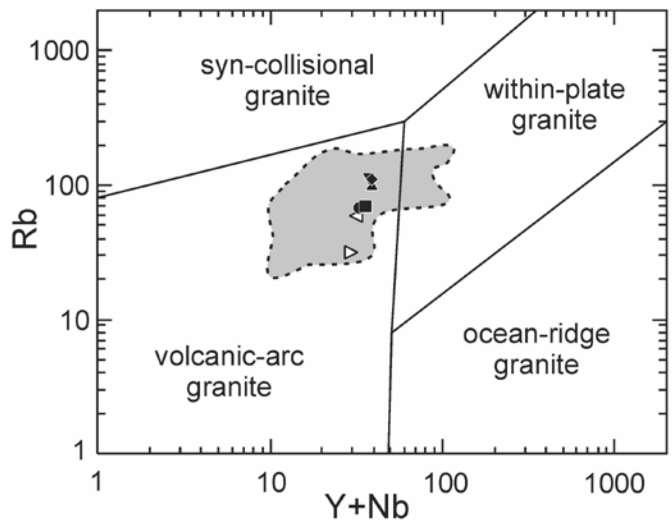

Fig. 10. **Tectonic setting discrimination diagram (after Pearce *et al.*1984) for samples from the Machias Seal Island quartz monzodiorite and enclaves compared to the field for plutons in the Brookville terrane. Symbols and field are as in Fig. 7.**

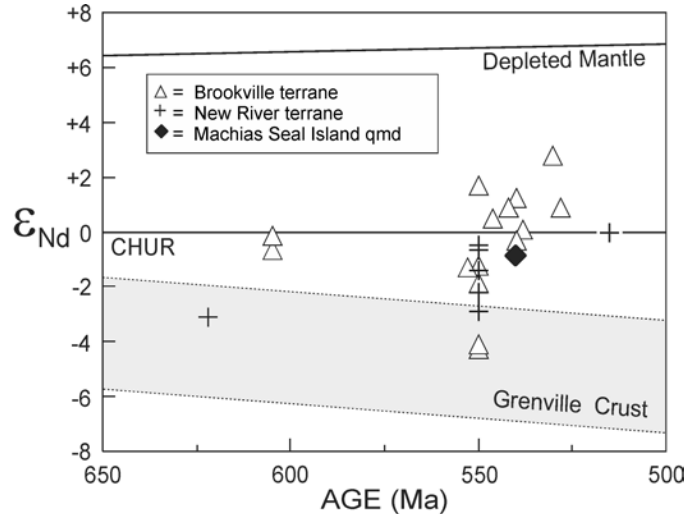

Fig. 11. **Epsilon Nd value for sample NB04-182 (data in Table A8) from the Machias Seal Island quartz monzodiorite compared to data from the Brookville and New River terrane taken from the compilations of Samson *et al.* (2000) and Barr *et al.* (2003).**

terrane supports the interpretation that Machias Seal Island is part of the Brookville terrane. Although it is the closest land area to Machias Seal Island, none of the rocks on Grand Manan Island is similar in age and petrological characteristics to the Machias Seal Island quartz monzodiorite. Much of Grand Manan Island is composed of Mesozoic basalt, and the remaining third of the island is dominated by volcanic and sedimentary rocks (Fyffe and Grant 2005; Black 2005; Miller *et al*. 2007). The Three Islands Granite forms islands south of the main island, but it has been dated at 611 Ma, much older than the ca. 540 Ma Machias Seal Island quartz monzodiorite. Two small plutons on Grand Manan Island have yielded Ediacaran-Early Cambrian ages of 547.3 ± 1.1 Ma (Miller *et al*. 2007) and 535 ± 2.5 Ma (P. Valverde-Vaquero, unpublished written report to L.R. Fyffe, 2003), similar to the age of the Machias Seal Island quartz monzodiorite, but both are granitic in composition and hence petrologically unlike the quartz monzodiorite (Black 2005).

The assemblage of pre-Mesozoic rocks on Grand Manan Island and their ages led to tentative correlation with the New River terrane in mainland New Brunswick (Miller *et al*. 2007; Fyffe *et al*. 2009). The relationship between the New River and Brookville terranes is uncertain, although both are interpreted to be part of Ganderia. The position of Machias Seal Island so close to Grand Manan Island supports the interpretation that both Brookville and New River terranes are part of Ganderia, whereas Avalonia is located farther offshore (Fig. 1). Geophysical data from the area (e.g., Hutchinson *et al*. 1988; Keen *et al*. 1991) are not sufficiently detailed to enable resolution of these details, but the results of this study are consistent with the interpretation that the Fundy Fault, previously identified to the southeast on the basis of geophysical data, marks the boundary between Ganderia and Avalonia (Fig. 1).

Overall, the results of this study show that the geology of Machias Seal Island is closely linked to that of mainland New Brunswick, not adjacent parts of Maine. The latter area is dominated by Silurian–Devonian granitoid rocks of the Coastal Maine magmatic province (e.g., Hogan and Sinha 1989).

CONCLUSIONS

Machias Seal Island is composed of plutonic rocks of similar age and petrological features to those of the Brookville terrane in mainland southern New Brunswick. They are more than 100 million years older than the granitoid rocks that characterize the Coastal Maine magmatic province, with which they had previously been correlated. Although direct links with rock units exposed on nearby Grand Manan Island cannot be made, some units there are of similar age, supporting Ganderian affinity for both areas.

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APPENDIX

Table A1a. Potassium feldspar compositions* from Machias Seal Island quartz monzodiorite and enclaves.

	weight %										cations calculated on the basis of 32 oxygen										end member components		
Sample	SiO_2	TiO_2	Al_2O_3	FeO^t	MnO	MgO	CaO	Na_2O	K_2O	Total	Si	Al	Fe^{3+}	Ti	Fe^{2+}	Mn	Mg	Ca	Na	K	%Ab	%An	%Or
NB04-176a	64.55	0.04	18.85	0.16	0.00	0.00	0.13	1.23	14.57	99.53	11.92	4.10	0.00	0.01	0.02	0.00	0.00	0.03	0.44	3.43	11.30	0.70	88.00
NB04-176a	64.41	0.00	18.36	0.01	0.01	0.00	0.05	0.50	14.79	98.13	12.03	4.04	0.00	0.00	0.00	0.00	0.00	0.01	0.18	3.53	4.90	0.30	94.90
NB04-179	64.48	0.01	18.72	0.00	0.00	0.00	0.00	0.32	16.06	99.59	11.95	4.09	0.00	0.00	0.00	0.00	0.00	0.00	0.12	3.80	2.90	0.00	97.10
NB04-179	63.71	0.00	18.72	0.00	0.00	0.00	0.16	0.39	15.67	98.66	11.92	4.12	0.00	0.00	0.00	0.00	0.00	0.03	0.14	3.74	3.60	0.80	95.60
NB04-179	64.53	0.04	19.34	0.16	0.00	0.00	0.26	3.13	11.53	98.98	11.86	4.19	0.00	0.01	0.03	0.00	0.00	0.05	1.12	2.70	28.80	1.30	69.80
NB04-179	65.03	0.07	18.41	0.04	0.03	0.01	0.12	0.89	14.24	98.84	12.04	4.01	0.00	0.01	0.01	0.01	0.00	0.02	0.32	3.36	8.60	0.60	90.70
NB04-179	65.27	0.00	18.78	0.03	0.00	0.00	0.04	1.58	13.15	98.85	12.02	4.07	0.00	0.00	0.01	0.00	0.00	0.01	0.56	3.09	15.40	0.20	84.40
NB04-179	64.89	0.00	18.49	0.01	0.00	0.00	0.00	0.47	15.07	98.93	12.03	4.04	0.00	0.00	0.00	0.00	0.00	0.00	0.17	3.57	4.50	0.00	95.50
NB04-182	63.51	0.04	18.50	0.04	0.02	0.00	0.05	0.30	15.78	98.22	11.94	4.10	0.00	0.01	0.01	0.00	0.00	0.01	0.11	3.78	2.80	0.20	97.00
NB04-182	64.62	0.01	18.57	0.05	0.04	0.00	0.06	0.39	15.08	98.82	12.01	4.06	0.00	0.00	0.01	0.01	0.00	0.01	0.14	3.57	3.80	0.30	95.90
NB04-182	65.11	0.05	18.50	0.08	0.02	0.00	0.04	0.62	14.83	99.25	12.03	4.03	0.00	0.01	0.01	0.00	0.00	0.01	0.22	3.50	6.00	0.20	93.80
NB04-182	64.99	0.03	18.55	0.11	0.02	0.00	0.08	0.66	14.60	99.04	12.02	4.04	0.00	0.00	0.02	0.00	0.00	0.02	0.24	3.45	6.40	0.40	93.20
NB04-183a	65.19	0.04	18.69	0.14	0.00	0.00	0.07	1.36	13.85	99.34	12.00	4.05	0.00	0.01	0.02	0.00	0.00	0.01	0.49	3.25	12.90	0.40	86.70
NB04-183a	64.86	0.11	18.48	0.18	0.01	0.00	0.14	2.26	12.42	98.46	12.00	4.03	0.00	0.02	0.03	0.00	0.00	0.03	0.81	2.93	21.50	0.70	77.70
NB04-183a	65.16	0.05	18.57	0.17	0.01	0.01	0.10	1.80	13.14	99.01	12.01	4.03	0.00	0.01	0.03	0.00	0.00	0.02	0.64	3.09	17.10	0.50	82.30
NB04-183d	65.21	0.03	18.54	0.12	0.00	0.00	0.09	1.45	13.51	98.95	12.03	4.03	0.00	0.00	0.02	0.00	0.00	0.02	0.52	3.18	14.00	0.50	85.50
NB04-183d	65.29	0.03	18.58	0.15	0.00	0.00	0.08	1.67	13.22	99.02	12.03	4.03	0.00	0.00	0.02	0.00	0.00	0.02	0.60	3.11	16.00	0.40	83.50
NB04-183d	65.08	0.04	18.67	0.17	0.00	0.01	0.10	2.39	12.21	98.67	12.00	4.05	0.00	0.01	0.03	0.00	0.00	0.02	0.85	2.87	22.80	0.50	76.70
NB04-183d	65.59	0.00	18.79	0.21	0.00	0.00	0.09	2.28	12.37	99.33	12.01	4.05	0.00	0.00	0.03	0.00	0.00	0.02	0.81	2.89	21.80	0.50	77.70
NB04-183d	64.73	0.05	18.48	0.09	0.01	0.01	0.10	2.15	12.49	98.11	12.01	4.04	0.00	0.01	0.01	0.00	0.00	0.02	0.77	2.96	20.60	0.50	78.80
NB04-183d	64.63	0.00	18.54	0.10	0.00	0.00	0.15	2.79	11.43	97.64	12.00	4.06	0.00	0.00	0.02	0.00	0.00	0.03	1.01	2.71	26.90	0.80	72.30

*Analyses by JEOL 8200 electron microprobe in the Dalhousie University Regional Electron Microprobe Laboratory.

Table A1b. Plagioclase feldspar compositions* from Machias Seal Island quartz monzodiorite and enclaves.

	weight %										cations calculated on the basis of 32 oxygen										end member components		
Sample	SiO_2	TiO_2	Al_2O_3	FeO^t	MnO	MgO	CaO	Na_2O	K_2O	Total	Si	Al	Fe^3	Ti	Fe^2	Mn	Mg	Ca	Na	K	%Ab	%An	%Or
NB04-182	62.90	0.01	23.68	0.17	0.00	0.00	4.45	8.96	0.47	100.63	11.09	4.92	0.00	0.00	0.02	0.00	0.00	0.84	3.06	0.11	76.40	21.00	2.60
NB04-176a	55.46	0.05	28.67	0.21	0.00	0.00	10.60	5.71	0.21	100.92	9.92	6.04	0.00	0.01	0.03	0.00	0.00	2.03	1.98	0.05	48.80	50.00	1.20
NB04-176a-r	58.46	0.03	25.66	0.22	0.00	0.00	7.31	7.57	0.26	99.50	10.52	5.44	0.00	0.00	0.03	0.00	0.00	1.41	2.64	0.06	64.30	34.30	1.50
NB04-176a-c	54.14	0.05	29.05	0.32	0.01	0.00	11.35	5.34	0.21	100.49	9.76	6.17	0.00	0.01	0.05	0.00	0.00	2.19	1.87	0.05	45.40	53.40	1.20
NB04-176a-r	57.15	0.02	27.36	0.17	0.00	0.00	8.77	6.71	0.20	100.38	10.22	5.76	0.00	0.00	0.03	0.00	0.00	1.68	2.33	0.05	57.40	41.50	1.10
NB04-176a	59.80	0.00	25.42	0.16	0.00	0.00	6.86	7.77	0.23	100.24	10.65	5.33	0.00	0.00	0.02	0.00	0.00	1.31	2.68	0.05	66.30	32.40	1.30
NB04-176a	46.40	0.00	34.63	0.17	0.00	0.00	16.87	1.48	0.03	99.58	8.55	7.51	0.00	0.00	0.03	0.00	0.00	3.33	0.53	0.01	13.70	86.10	0.20
NB04-179-c	55.24	0.00	28.33	0.18	0.00	0.00	10.10	5.83	0.17	99.85	9.97	6.02	0.00	0.00	0.03	0.00	0.00	1.95	2.04	0.04	50.60	48.40	1.00
NB04-179-r	60.21	0.00	25.16	0.18	0.00	0.00	6.27	7.90	0.29	100.00	10.73	5.28	0.00	0.00	0.03	0.00	0.00	1.20	2.73	0.07	68.40	30.00	1.60
NB04-179-c	55.67	0.00	28.45	0.26	0.00	0.00	10.32	5.75	0.22	100.67	9.97	6.00	0.00	0.00	0.04	0.00	0.00	1.98	2.00	0.05	49.60	49.20	1.20
NB04-179-c	54.52	0.01	29.46	0.31	0.00	0.00	11.11	5.31	0.21	100.92	9.77	6.22	0.00	0.00	0.05	0.00	0.00	2.13	1.85	0.05	45.80	53.00	1.20
NB04-179-r	61.26	0.00	24.92	0.18	0.00	0.00	5.87	8.32	0.37	100.93	10.81	5.18	0.00	0.00	0.03	0.00	0.00	1.11	2.85	0.08	70.50	27.50	2.10
NB04-179	60.99	0.00	25.22	0.17	0.00	0.00	6.35	8.02	0.38	101.13	10.75	5.24	0.00	0.00	0.03	0.00	0.00	1.20	2.74	0.09	68.10	29.80	2.10
NB04-179	60.04	0.02	25.47	0.15	0.02	0.00	6.63	7.98	0.28	100.59	10.66	5.32	0.00	0.00	0.02	0.00	0.00	1.26	2.75	0.06	67.50	31.00	1.50
NB04-179	59.63	0.00	25.79	0.23	0.00	0.00	7.01	7.50	0.29	100.45	10.60	5.40	0.00	0.00	0.03	0.00	0.00	1.34	2.59	0.07	64.90	33.50	1.70
NB04-179	61.44	0.00	24.47	0.12	0.00	0.00	5.51	8.48	0.40	100.42	10.89	5.11	0.00	0.00	0.02	0.00	0.00	1.05	2.91	0.09	71.90	25.80	2.20
NB04-182	55.09	0.03	28.86	0.24	0.02	0.01	10.10	5.57	0.21	100.13	9.91	6.12	0.00	0.00	0.04	0.00	0.00	1.95	1.94	0.05	49.30	49.40	1.20
NB04-182	55.25	0.03	28.04	0.29	0.01	0.19	9.63	5.93	0.19	99.56	10.00	5.98	0.00	0.00	0.04	0.00	0.05	1.87	2.08	0.04	52.10	46.80	1.10
NB04-182	62.22	0.00	24.49	0.16	0.03	0.00	5.38	8.72	0.29	101.29	10.92	5.06	0.00	0.00	0.02	0.00	0.00	1.01	2.97	0.07	73.40	25.00	1.60
NB04-183a-c	50.94	0.05	32.32	0.26	0.00	0.00	14.56	3.58	0.10	101.80	9.14	6.83	0.00	0.01	0.04	0.00	0.00	2.80	1.24	0.02	30.60	68.90	0.50
NB04-183a-c	44.45	0.00	35.78	0.29	0.00	0.00	19.02	0.92	0.00	100.46	8.19	7.76	0.00	0.00	0.04	0.00	0.00	3.75	0.33	0.00	8.10	91.90	0.00
NB04-183d	55.79	0.02	27.82	0.28	0.00	0.02	9.54	6.02	0.26	99.75	10.07	5.91	0.00	0.00	0.04	0.00	0.01	1.85	2.11	0.06	52.50	46.00	1.50
NB04-183a	59.53	0.02	25.32	0.20	0.01	0.00	6.77	7.91	0.29	100.05	10.63	5.33	0.00	0.00	0.03	0.00	0.00	1.30	2.74	0.07	66.80	31.60	1.60
NB04-183a	58.54	0.02	26.24	0.12	0.03	0.00	7.64	7.37	0.19	100.15	10.46	5.52	0.00	0.00	0.02	0.01	0.00	1.46	2.55	0.04	62.90	36.00	1.10
NB04-183a	55.32	0.02	28.10	0.27	0.02	0.00	9.78	5.92	0.23	99.66	10.00	5.98	0.00	0.00	0.04	0.00	0.00	1.90	2.08	0.05	51.60	47.10	1.30
NB04-183a	54.14	0.05	28.98	0.19	0.02	0.01	10.70	5.28	0.21	99.58	9.82	6.19	0.00	0.01	0.03	0.00	0.00	2.08	1.86	0.05	46.60	52.20	1.20
NB04-183a	58.07	0.04	26.62	0.20	0.03	0.00	7.83	7.15	0.28	100.22	10.38	5.61	0.00	0.01	0.03	0.01	0.00	1.50	2.48	0.06	61.30	37.10	1.60
NB04-183d	56.15	0.00	27.47	0.26	0.00	0.00	9.62	6.29	0.27	100.06	10.11	5.83	0.00	0.00	0.04	0.00	0.00	1.86	2.20	0.06	53.40	45.10	1.50
NB04-183d	57.14	0.00	27.50	0.27	0.00	0.01	8.86	6.47	0.32	100.57	10.21	5.79	0.00	0.00	0.04	0.00	0.00	1.70	2.24	0.07	55.90	42.30	1.80
NB04-183d	46.38	0.01	34.05	0.39	0.01	0.02	16.28	1.62	0.05	98.81	8.61	7.44	0.00	0.00	0.06	0.00	0.01	3.24	0.58	0.01	15.20	84.50	0.30
NB04-183d	54.50	0.03	28.85	0.26	0.01	0.01	10.26	5.54	0.19	99.65	9.87	6.15	0.00	0.00	0.04	0.00	0.00	1.99	1.94	0.04	48.90	50.00	1.10
NB04-183d	59.64	0.01	25.34	0.15	0.00	0.01	6.69	7.73	0.34	99.91	10.66	5.33	0.00	0.00	0.02	0.00	0.00	1.28	2.68	0.08	66.40	31.70	1.90
NB04-183d	56.50	0.00	27.85	0.20	0.00	0.00	9.83	6.37	0.26	101.01	10.08	5.85	0.00	0.00	0.03	0.00	0.00	1.88	2.21	0.06	53.20	45.40	1.40
NB04-183d	60.67	0.01	24.70	0.25	0.00	0.01	6.05	8.09	0.34	100.12	10.80	5.18	0.00	0.00	0.04	0.00	0.00	1.15	2.79	0.08	69.40	28.70	1.90
NB04-183d	60.66	0.01	24.86	0.16	0.00	0.00	6.08	8.13	0.38	100.28	10.78	5.20	0.00	0.00	0.02	0.00	0.00	1.16	2.80	0.09	69.20	28.60	2.10
NB04-183d	58.80	0.00	26.43	0.07	0.00	0.00	7.97	7.41	0.19	100.87	10.44	5.53	0.00	0.00	0.01	0.00	0.00	1.52	2.55	0.04	62.10	36.90	1.00
NB04-183d	54.11	0.00	28.60	0.27	0.00	0.01	10.80	5.31	0.20	99.30	9.85	6.13	0.00	0.00	0.04	0.00	0.00	2.11	1.87	0.05	46.50	52.30	1.20
NB04-183d	54.09	0.00	28.65	0.16	0.00	0.00	10.61	5.47	0.19	99.17	9.85	6.14	0.00	0.00	0.02	0.00	0.00	2.07	1.93	0.04	47.80	51.10	1.10
NB04-183d	45.85	0.00	33.49	0.18	0.00	0.00	16.43	2.20	0.03	98.18	8.59	7.39	0.00	0.00	0.03	0.00	0.00	3.30	0.80	0.01	19.50	80.40	0.20
NB04-183d	55.56	0.00	27.80	0.13	0.00	0.00	9.30	6.13	0.22	99.14	10.08	5.94	0.00	0.00	0.02	0.00	0.00	1.81	2.16	0.05	53.70	45.00	1.20
NB04-183d	53.98	0.00	29.48	0.28	0.00	0.01	11.85	5.01	0.20	100.81	9.70	6.24	0.00	0.00	0.04	0.00	0.00	2.28	1.75	0.05	42.90	56.00	1.10
NB04-183d	53.91	0.00	28.71	0.12	0.00	0.00	10.67	5.49	0.18	99.08	9.83	6.16	0.00	0.00	0.02	0.00	0.00	2.08	1.94	0.04	47.70	51.30	1.00
NB04-183d	52.16	0.00	30.01	0.31	0.00	0.01	12.10	4.68	0.16	99.44	9.52	6.45	0.00	0.00	0.05	0.00	0.00	2.37	1.66	0.04	40.80	58.30	0.90
NB04-183d	54.88	0.05	28.64	0.20	0.00	0.01	10.61	5.63	0.19	100.21	9.89	6.08	0.00	0.01	0.03	0.00	0.00	2.05	1.97	0.04	48.40	50.50	1.10
NB04-183d	60.58	0.06	24.93	0.25	0.00	0.00	6.06	8.22	0.36	100.47	10.76	5.21	0.00	0.01	0.04	0.00	0.00	1.15	2.83	0.08	69.60	28.40	2.00
NB04-183d	53.13	0.00	29.40	0.18	0.00	0.00	11.79	4.97	0.14	99.61	9.66	6.30	0.00	0.00	0.03	0.00	0.00	2.30	1.75	0.03	42.90	56.30	0.80

*Analyses by JEOL 8200 electron microprobe in the Dalhousie University Regional Electron Microprobe Laboratory.

Table A2. Amphibole compositions* from Machias Seal Island quartz monzodiorite and enclaves.

	weight %											cations calculated on the basis of 23 oxygen															
Sample	SiO_2	TiO_2	Al_2O_3	FeO^t	Cr_2O_3	MnO	MgO	CaO	Na_2O	K_2O	Total	TSi	TAl	TFe^{3+}	CAl	CCr	CFe^{3+}	CTi	CMg	CFe^{2+}	CMn	BFe^{2+}	BMn	BCa	BNa	ANa	AK
NB04-176a	48.13	0.81	5.85	17.16	0.08	0.48	12.84	11.43	0.94	0.56	98.20	7.04	0.96	0.01	0.05	0.01	0.58	0.09	2.80	1.45	0.03	0.07	0.03	1.79	0.11	0.16	0.10
NB04-176a	47.58	0.76	5.88	17.61	0.00	0.42	11.81	10.24	1.19	0.54	96.03	7.14	0.86	0.00	0.18	0.00	0.51	0.09	2.64	1.56	0.03	0.14	0.03	1.65	0.17	0.18	0.10
NB04-176a	47.68	0.84	5.93	16.78	0.02	0.36	12.50	10.37	1.19	0.57	96.22	7.11	0.89	0.00	0.15	0.00	0.51	0.09	2.78	1.44	0.02	0.14	0.02	1.66	0.17	0.17	0.11
NB04-179	47.86	1.19	5.78	17.78	0.06	0.57	11.79	11.31	1.32	0.59	98.19	7.08	0.92	0.00	0.09	0.01	0.32	0.13	2.60	1.82	0.04	0.06	0.04	1.79	0.11	0.27	0.11
NB04-179	46.89	1.38	6.54	17.70	0.00	0.46	11.34	10.17	1.48	0.66	96.62	7.04	0.96	0.00	0.20	0.00	0.44	0.16	2.54	1.64	0.03	0.14	0.03	1.64	0.19	0.24	0.13
NB04-179	47.16	1.25	6.40	17.70	0.00	0.48	11.37	10.20	1.59	0.66	96.81	7.07	0.93	0.00	0.21	0.00	0.41	0.14	2.54	1.67	0.03	0.14	0.03	1.64	0.19	0.27	0.13
NB04-182	46.49	1.41	6.52	17.83	0.07	0.46	11.50	11.42	1.36	0.71	97.69	6.93	1.07	0.00	0.08	0.01	0.33	0.16	2.56	1.85	0.03	0.05	0.03	1.82	0.09	0.30	0.13
NB04-182	46.29	1.50	6.79	18.14	0.09	0.55	11.33	11.45	1.44	0.76	98.25	6.88	1.12	0.00	0.07	0.01	0.33	0.17	2.51	1.88	0.03	0.05	0.04	1.82	0.09	0.32	0.14
NB04-182	49.51	0.60	4.84	16.71	0.12	0.56	12.72	10.72	1.07	0.44	97.17	7.30	0.70	0.00	0.14	0.01	0.43	0.07	2.80	1.52	0.04	0.11	0.04	1.69	0.15	0.16	0.08
NB04-183a	47.85	1.01	5.87	17.78	0.05	0.37	12.22	11.28	1.05	0.56	97.99	7.05	0.95	0.00	0.07	0.01	0.49	0.11	2.68	1.62	0.02	0.08	0.02	1.78	0.12	0.18	0.11
NB04-183d	48.41	0.28	5.64	18.18	0.05	0.45	11.93	10.53	0.94	0.53	96.89	7.18	0.82	0.00	0.17	0.01	0.56	0.03	2.64	1.57	0.03	0.13	0.03	1.67	0.13	0.14	0.10
NB04-183d	47.90	0.83	5.67	17.19	0.08	0.31	12.32	10.08	1.13	0.55	95.98	7.15	0.85	0.00	0.15	0.01	0.55	0.09	2.74	1.43	0.02	0.16	0.02	1.61	0.16	0.17	0.11
NB04-183d	47.04	1.01	6.37	18.55	0.16	0.37	11.90	11.11	1.23	0.68	98.25	6.93	1.05	0.02	0.06	0.02	0.55	0.11	2.61	1.63	0.02	0.09	0.02	1.75	0.13	0.22	0.13

*Analyses by JEOL 8200 electron microprobe in the Dalhousie University Regional Electron Microprobe Laboratory.

Table A3. Pyroxene compositions* from Machias Seal Island quartz monzodiorite and enclaves.

	weight %											numbers of cations calculate								
Sample	SiO_2	TiO_2	Al_2O_3	FeO^t	Cr_2O_3	MnO	MgO	CaO	Na_2O	K_2O	Total	TSi	TAl	TFe^{3+}	M1Al	M1Ti	$M1Fe^{3+}$	$M1Fe^{2+}$	M1Cr	M
NB04-176a	51.26	0.44	2.73	8.61	0.00	0.25	13.71	21.18	0.26	0.01	98.45	1.94	0.06	0.00	0.06	0.01	0.00	0.16	0.00	
NB04-176a	52.32	0.14	0.47	11.66	0.10	0.42	13.04	22.40	0.24	0.00	100.80	1.95	0.02	0.03	0.00	0.00	0.05	0.22	0.00	
NB04-179	52.09	0.47	1.36	14.69	0.10	0.47	14.00	17.86	0.30	0.00	101.34	1.94	0.06	0.00	0.00	0.01	0.05	0.15	0.00	
NB04-179	52.34	0.29	1.04	9.35	0.01	0.41	14.00	22.72	0.23	0.19	100.58	1.94	0.05	0.01	0.00	0.01	0.07	0.15	0.00	
NB04-179	53.18	0.03	0.12	9.06	0.03	0.56	13.53	24.02	0.19	0.00	100.73	1.98	0.01	0.02	0.00	0.00	0.04	0.21	0.00	
NB04-183a	50.67	0.59	2.05	12.36	0.19	0.49	11.57	19.64	0.41	0.05	98.02	1.96	0.04	0.00	0.05	0.02	0.00	0.26	0.01	
NB04-183a	52.29	0.24	0.79	12.22	0.08	0.54	12.00	20.00	0.31	0.04	98.51	2.01	0.00	0.00	0.04	0.01	0.00	0.27	0.00	
NB04-183a	52.07	0.36	0.94	12.42	0.08	0.42	12.79	21.66	0.33	0.03	101.08	1.94	0.04	0.02	0.00	0.01	0.06	0.22	0.00	
NB04-183a	50.18	0.50	4.17	8.79	0.71	0.25	13.69	21.80	0.38	0.01	100.47	1.86	0.14	0.00	0.04	0.01	0.08	0.09	0.02	
NB04-183d	51.61	0.36	1.63	11.71	0.00	0.42	13.32	19.26	0.30	0.02	98.63	1.97	0.04	0.00	0.04	0.01	0.00	0.20	0.00	
NB04-183d	52.45	0.28	0.80	11.63	0.09	0.40	13.02	19.32	0.27	0.04	98.30	2.01	0.00	0.00	0.04	0.01	0.00	0.21	0.00	
NB04-183d	51.99	0.45	1.09	11.77	0.07	0.37	12.76	19.55	0.34	0.05	98.44	1.99	0.01	0.00	0.04	0.01	0.00	0.22	0.00	
NB04-183d	51.68	0.47	1.23	11.87	0.08	0.37	12.56	19.82	0.34	0.04	98.46	1.98	0.02	0.00	0.03	0.01	0.00	0.23	0.00	
NB04-183d	52.10	0.35	1.03	11.94	0.09	0.51	11.96	20.01	0.33	0.03	98.35	2.00	0.00	0.00	0.05	0.01	0.00	0.26	0.00	
NB04-183d	51.59	0.32	1.20	11.51	0.00	0.43	12.30	21.15	0.30	0.01	98.81	1.97	0.03	0.00	0.02	0.01	0.01	0.26	0.00	
NB04-183d	51.91	0.33	1.17	11.53	0.00	0.43	12.28	21.32	0.32	0.02	99.31	1.97	0.03	0.00	0.02	0.01	0.01	0.26	0.00	
NB04-176a	51.36	0.26	0.79	27.84	0.02	0.99	17.04	1.48	0.01	0.03	99.82	1.98	0.02	0.00	0.02	0.01	0.00	0.00	0.00	
NB04-176a	51.71	0.33	0.60	25.96	0.08	0.86	19.56	1.56	0.01	0.01	100.67	1.95	0.03	0.02	0.00	0.01	0.03	0.00	0.00	
NB04-176a	52.67	0.19	1.06	22.21	0.00	0.57	21.18	1.58	0.00	0.00	99.46	1.98	0.02	0.00	0.03	0.01	0.00	0.00	0.00	
NB04-176a	51.79	0.28	0.66	25.44	0.11	0.76	18.72	2.51	0.02	0.01	100.29	1.97	0.03	0.01	0.00	0.01	0.02	0.00	0.00	
NB04-183a	51.80	0.27	0.36	27.06	0.10	0.83	18.62	0.88	0.00	0.04	99.96	1.98	0.02	0.00	0.00	0.01	0.00	0.00	0.00	
NB04-183a	52.33	0.31	0.70	25.53	0.08	0.70	19.33	1.36	0.02	0.03	100.39	1.98	0.02	0.00	0.01	0.01	0.00	0.00	0.00	
NB04-183a	52.29	0.22	1.23	23.34	0.09	0.66	21.42	1.56	0.00	0.00	100.81	1.94	0.05	0.00	0.00	0.01	0.04	0.00	0.00	
NB04-183a	51.82	0.32	0.53	27.10	0.09	0.77	18.40	1.71	0.01	0.01	100.77	1.97	0.02	0.01	0.00	0.01	0.01	0.00	0.00	
NB04-183d	53.76	0.13	0.27	25.53	0.06	1.06	15.55	0.81	0.06	0.04	97.27	2.14	0.00	0.00	0.01	0.00	0.00	0.06	0.00	
NB04-183d	51.83	0.19	0.93	23.94	0.00	0.69	19.51	1.01	0.01	0.03	98.14	2.00	0.01	0.00	0.04	0.01	0.00	0.00	0.00	
NB04-183d	51.35	0.36	0.54	28.27	0.10	0.78	16.95	1.32	0.03	0.03	99.73	1.99	0.01	0.00	0.01	0.01	0.00	0.00	0.00	
NB04-183d	51.37	0.21	0.84	26.86	0.09	0.79	17.63	1.41	0.02	0.03	99.25	1.98	0.02	0.00	0.02	0.01	0.00	0.00	0.00	
NB04-183d	51.87	0.29	0.61	25.95	0.10	0.72	18.85	1.46	0.01	0.04	99.90	1.98	0.02	0.00	0.01	0.01	0.00	0.00	0.00	
NB04-183d	51.69	0.37	0.61	26.87	0.08	0.73	17.61	1.50	0.01	0.03	99.50	1.99	0.01	0.00	0.02	0.01	0.00	0.00	0.00	

*Analyses by JEOL 8200 electron microprobe in the Dalhousie University Regional Electron Microprobe Laboratory. T, M1, and M2 are sites in the pyroxene crystal structure

Table A4. Biotite compositions* from Machias Seal Island quartz monzodiorite and enclaves.

	weight %											cations calculated on the basis of 24 oxygen											
Sample	SiO_2	TiO_2	Al_2O_3	Cr_2O_3	FeO^t	MnO	MgO	CaO	Na_2O	K_2O	Total	Si	Al^{IV}	Al^{VI}	Ti	Fe^{2+}	Cr	Mn	Mg	Ca	Na	K	Fe/Fe+Mg
NB04-176a	37.05	3.98	13.08	0.00	20.70	0.19	10.59	0.00	0.11	8.49	94.19	6.00	2.00	0.50	0.49	2.80	0.00	0.03	2.56	0.00	0.04	1.75	0.52
NB04-179	36.76	4.98	13.54	0.06	21.54	0.25	10.23	0.01	0.15	9.45	96.96	5.84	2.16	0.38	0.60	2.86	0.01	0.03	2.42	0.00	0.05	1.92	0.54
NB04-179	37.30	5.16	13.13	0.10	20.64	0.22	10.65	0.01	0.14	9.03	96.37	5.92	2.08	0.37	0.62	2.74	0.01	0.03	2.52	0.00	0.04	1.83	0.52
NB04-179	36.55	4.72	12.84	0.11	21.33	0.26	9.74	0.02	0.07	8.67	94.31	5.95	2.05	0.41	0.58	2.91	0.01	0.04	2.37	0.00	0.02	1.80	0.55
NB04-179	36.80	4.79	12.81	0.11	20.56	0.27	10.48	0.01	0.12	8.59	94.54	5.95	2.05	0.39	0.58	2.78	0.01	0.04	2.53	0.00	0.04	1.77	0.52
NB04-179	37.26	4.34	12.89	0.00	20.76	0.23	10.54	0.04	0.08	8.44	94.58	6.01	2.00	0.46	0.53	2.80	0.00	0.03	2.53	0.01	0.03	1.74	0.52
NB04-179	37.39	4.66	12.86	0.00	20.50	0.20	10.98	0.01	0.11	8.66	95.37	5.98	2.02	0.40	0.56	2.74	0.00	0.03	2.62	0.00	0.03	1.77	0.51
NB04-182	36.89	5.06	12.77	0.11	21.28	0.25	10.40	0.02	0.09	9.15	96.01	5.91	2.09	0.32	0.61	2.85	0.01	0.03	2.48	0.00	0.03	1.87	0.53
NB04-182	37.11	4.70	12.68	0.11	20.47	0.27	10.70	0.03	0.18	8.73	94.98	5.97	2.03	0.38	0.57	2.76	0.01	0.04	2.57	0.01	0.06	1.79	0.52
NB04-182	38.21	4.58	12.48	0.07	19.91	0.26	11.24	0.01	0.18	8.74	95.68	6.07	2.00	0.40	0.55	2.64	0.01	0.04	2.66	0.00	0.06	1.77	0.50
NB04-182	37.01	4.75	12.75	0.08	20.99	0.26	10.41	0.01	0.15	8.77	95.18	5.96	2.04	0.38	0.58	2.83	0.01	0.04	2.50	0.00	0.05	1.80	0.53
NB04-183a	37.39	4.42	13.24	0.14	21.17	0.16	11.31	0.04	0.06	9.17	97.10	5.90	2.10	0.37	0.53	2.80	0.02	0.02	2.66	0.01	0.02	1.85	0.51
NB04-183a	37.20	4.62	13.30	0.10	21.25	0.18	11.33	0.02	0.07	9.16	97.22	5.87	2.13	0.34	0.55	2.81	0.01	0.02	2.67	0.00	0.02	1.84	0.51
NB04-183a	37.52	4.36	12.92	0.08	20.40	0.17	11.36	0.04	0.08	8.62	95.55	5.98	2.02	0.41	0.52	2.72	0.01	0.02	2.70	0.01	0.03	1.75	0.50
NB04-183a	37.19	3.93	13.26	0.09	20.04	0.17	11.33	0.03	0.07	8.68	94.79	5.97	2.03	0.48	0.48	2.69	0.01	0.02	2.71	0.01	0.02	1.78	0.50
NB04-183a	37.15	3.86	13.39	0.10	19.69	0.18	11.06	0.08	0.07	8.48	94.06	5.99	2.01	0.54	0.47	2.66	0.01	0.03	2.66	0.01	0.02	1.75	0.50
NB04-183d	37.03	4.26	13.18	0.01	20.08	0.16	10.87	0.07	0.07	8.48	94.21	5.98	2.02	0.48	0.52	2.71	0.00	0.02	2.62	0.01	0.02	1.75	0.51
NB04-183d	36.96	3.80	12.81	0.00	19.99	0.16	10.91	0.09	0.08	8.31	93.11	6.03	2.00	0.50	0.47	2.73	0.00	0.02	2.66	0.02	0.03	1.73	0.51
NB04-183d	37.31	3.88	12.88	0.11	20.37	0.17	11.22	0.07	0.07	8.27	94.35	6.01	2.00	0.46	0.47	2.75	0.01	0.02	2.70	0.01	0.02	1.70	0.50
NB04-183d	36.75	4.57	13.63	0.11	21.26	0.14	10.26	0.03	0.05	8.78	95.58	5.89	2.11	0.46	0.55	2.85	0.01	0.02	2.45	0.01	0.02	1.80	0.54
NB04-183d	37.42	3.83	13.08	0.09	20.07	0.16	11.43	0.05	0.06	8.80	94.99	6.00	2.00	0.47	0.46	2.69	0.01	0.02	2.73	0.01	0.02	1.80	0.50
NB04-183d	36.45	3.99	13.53	0.10	21.21	0.12	11.38	0.03	0.07	9.47	96.34	5.83	2.17	0.38	0.48	2.84	0.01	0.02	2.71	0.01	0.02	1.93	0.51
NB04-183d	36.49	3.89	13.30	0.19	21.73	0.16	10.92	0.05	0.12	9.29	96.13	5.86	2.14	0.37	0.47	2.92	0.02	0.02	2.61	0.01	0.04	1.90	0.53

*Analyses by JEOL 8200 electron microprobe in the Dalhousie University Regional Electron Microprobe Laboratory.

Table A5. U-Pb TIMS analytical data for Machias Seal Island quartz monzodiorite sample NB04-182.

Sample description[1]	Wt (mg)	U (ppm)	Pb^2 (ppm)	$^{206}Pb/^{204}U$ (meas)	total common Pb (pg)	^{208}Pb (%)	Isotopic Ratios[3]						Correlation coefficient	Isotopic Ages (Ma)[4]			
							$^{206}Pb/^{238}U$	error	$^{207}Pb/^{235}U$	error	$^{207}Pb/^{206}Pb$	error		$^{206}Pb/^{238}U$	error	$^{207}Pb/^{206}Pb$	error
B: N2,+134,5,a	0.014	339	34.6	4340	6	22.5	0.08681	0.15	0.6976	0.31	0.05829	0.25	0.60	536.6	1.5	540.5	11.1
B2: N2,+134,1,ca	0.002	412	43.7	1161	4	24.6	0.08773	0.14	0.7062	0.69	0.05839	0.65	0.44	542.1	1.5	544.3	28.2
C: N2,+134,5,a	0.018	423	43	4465	9	21.4	0.08772	0.11	0.7051	0.17	0.0583	0.11	0.80	542.0	1.2	540.9	4.6
D: N2,+134,5,a	0.016	416	41.8	5031	7	21.1	0.08698	0.11	0.7003	0.24	0.05839	0.28	0.73	537.7	1.1	544.6	7.7
D2: N2,+134,1,ca	0.002	1422	148	5901	3	24.1	0.08687	0.09	0.6999	0.18	0.05843	0.13	0.67	537.0	0.9	546.0	5.8
E: N2,+134,5,a	0.013	294	30	3291	6	22.8	0.08635	0.15	0.6932	0.27	0.05823	0.21	0.62	533.9	1.5	538.4	9.3
E2: N2,+134,1,ca	0.010	57	6	1286	11	24.8	0.08725	0.40	0.7022	0.89	0.05837	0.81	0.42	539.3	4.1	543.8	35.3

[1] N2 = non-magnetic at 2 degree side slope on Frantz magnetic separator; grain size given in microns; number of grains; a = physically abraded; ca = chemically abraded; [2] radiogenic Pb, corrected for blank, spike, and initial common Pb; [3] corrected for blank Pb and U, and common Pb; errors given at 1 standard deviation; [4] corrected for blank Pb and U, and common Pb; errors given at 2 sigma level.

Table A6. Whole-rock chemical analyses* of samples from the Machias Seal Island quartz monzodiorite and enclaves.

	major oxides (wt %)												trace elements (ppm)																	
Sample	SiO_2	TiO_2	Al_2O_3	$Fe_2O_3^t$	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Total	Ba	Rb	Sr	Y	Zr	Nb	U	Th	Ni	Cr	Co	V	Cu	Zn	Ga	Pb	La	Nd
NB04-176A	59.33	0.78	16.76	7.25	0.12	3.06	6.45	3.2	2.41	0.21	0.49	100.06	290	69	228	24	156	9	2	10	3	14	52	122	35	77	18	9	37	29
NB04-178	59.79	0.76	16.72	6.93	0.11	2.77	6.15	3.28	2.41	0.2	0.79	99.91	271	70	227	27	190	9	2	13	<3	13	52	118	33	72	17	11	42	31
NB04-179	62.22	0.661	15.54	5.72	0.094	2.33	4.98	3.19	3.21	0.17	0.47	98.59	270	103	182	29	200	10	3	10	11	8	53	99	38	64	16	12	45	34
NB04-180	62.29	0.629	15.7	5.32	0.087	2.06	4.19	3.28	3.43	0.178	1.53	98.69	282	111	217	28	204	10	3	10	<3	6	46	75	33	63	16	9	47	34
NB04-182	63.17	0.637	15.38	5.29	0.088	2.11	4.38	3.17	3.41	0.15	1.18	98.97	331	110	174	28	205	11	2	10	3	7	52	93	22	68	15	19	42	29
NB04-183b	56.44	0.75	16.7	8.28	0.13	3.76	7.44	3.59	1.64	0.25	0.70	99.73	264	59.2	253.2	25.4	160.6	6.2	1.3	6.9	7.1	nd	69.4	198	17.7	27	16	7.4	21	24.6
NB04-183c	53.74	0.83	16.66	9.48	0.15	4.59	8.85	3.86	0.92	0.24	0.40	99.74	138	31.6	276.4	24.3	86.2	5.5	1.1	3.9	5.5	nd	75.4	230	13.7	17	15.7	6.1	19.9	26

*Analysed (except samples NB04-183b and c) by X-ray Fluorescence at the Regional Geochemical Centre, Saint Mary's University, Halifax, Nova Scotia. Major elements and some trace elements were measured using fused glass disks and other trace elements were measured using pressed powder pellets. Analytical error is generally less than 5% for major elements and 2–10% for trace elements. $Fe_2O_3^t$ is total Fe as Fe_2O_3. LOI is loss on ignition at 1000°C; nd = not determined. Samples NB04-183b and c were analysed at ACME, Vancouver, by ICP-MS.

Table A7. REE, Hf, and Ta data* from the Machias Seal Island quartz monzodiorite and enclaves.

Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta
NB04-176a	24.937	54.129	6.633	27.506	5.311	1.182	4.593	0.796	4.849	0.955	2.790	0.432	2.758	0.443	3.948	0.723
NB04-182	70.193	141.730	16.762	32.120	6.336	1.141	5.377	0.819	5.130	1.089	3.267	0.482	3.261	0.503	5.648	1.723
NB04-183B	21.000	48.300	6.030	24.600	4.550	1.140	4.430	0.710	4.430	0.830	2.600	0.340	2.480	0.390	4.500	0.700
NB04-183C	19.900	47.100	6.100	26.000	5.150	1.240	4.640	0.720	4.240	0.780	2.540	0.300	2.240	0.350	2.700	0.800

*Samples NB04-176a and 182 were analyzed at Memorial University of Newfoundland by ICP-MS, using the Na_2O_2 sinter method (Longerich *et al* . 1990). Samples NB04-183b, c were analysed by ICP-MS (aqua regia disgestion) at ACME Analytical Laboratories Ltd., Vancouver, BC.

Table A8. Sm-Nd data* for sample NB04-182.

Sample	Age (t)	Nd (ppm)	Sm (ppm)	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$	2 sigma	Epsilon Nd(0)	Epsilon Nd(t)	T(DM) DeP
NB04-182	440	29.84	5.950	0.1205	0.512328	4	-6.1	-0.8	1170

*Sm and Nd concentrations and Nd isotopic compositions were analyzed at Memorial University of Newfoundland. The in-run precisions on the Nd isotopic ratio are given at 95% confidence level. Errors on Nd isotopic compositions are <0.002% and errors on the $^{147}Sm/^{144}Nd$ ratio are estimated to be lower than 0.1%. The epsilon Nd values are calculated using $^{147}Sm/^{144}Nd = 0.1967$ and $^{143}Nd/^{144}Nd = 0.512638$ values for the present-day chondrite uniform reservoir (CHUR). The ^{147}Sm decay constant is $6.54\ 10^{-12}\ y^{-1}$ (Steiger and Jäger 1977). T(DM) was calculated following the DePaolo (1988) mantle model.