Revised stratigraphy in the eastern Meguma terrane, Nova Scotia, Canada, and variations in whole-rock chemical and Sm–Nd isotopic compositions of the Goldenville and Halifax groups

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ABSTRACT

As a result of new geological mapping, the Goldenville and Halifax groups in the eastern Meguma terrane have been divided into formations. They have a total stratigraphic thickness of about 7750 m and correspond to only the upper half of the Goldenville Group and lower half of the Halifax Group in the northwestern and southeastern areas of the terrane. The revised stratigraphy combined with compiled and new whole-rock major and trace element and Sm–Nd isotopic analyses enable more detailed documentation of the chemical changes with stratigraphy that were demonstrated in previous studies. Based on chemical compositions, the protolith compositions of the analysed samples range from lithic arenite to wacke to shale. Major and trace element characteristics are consistent with deposition in an active continental margin, basins associated with island arcs, or most likely at a passive continental margin with volcanic rocks in the source area. Chemical compositions show a scattered but overall increasing abundance of lithophile elements such as La and Th with stratigraphic position. Epsilon $_{Nd(t)}$ values become increasingly negative up-section, and depleted mantle model ages become increasingly older. The data are consistent with increased mixing between sediments derived from Mesoproterozoic upper crustal sources and sediments derived from a magmatic arc. These data are consistent with published detrital zircon patterns which show increasing amounts of ca. 2 Ga zircon with decreasing age, and with a source area comprising a Pan-African (800–540 Ma) volcanic arc and/or active margin magmatism and mainly Eburnean crust, most likely in the West African craton.

RÉSUMÉ

À la suite de nouveaux travaux de cartographie géologique, les groupes de Goldenville et d'Halifax dans l'est du terrane de Meguma ont été subdivisés en formations. Ils ont une épaisseur stratigraphique totale d'environ 7 750 mètres et correspondent à seulement la moitié supérieure du groupe de Goldenville et à la moitié inférieure du groupe d'Halifax dans les secteurs nord-ouest et sud-est du terrane. La stratigraphie révisée combinée à des données compilées et à de nouvelles analyses des compositions isotopiques en Sm–Nd et en éléments majeurs et traces de roche totale permet une documentation plus détaillée des changements chimiques de la stratigraphie ayant été révélés dans des études antérieures. D'après les compositions chimiques, les compositions protolithiques des échantillons analysés varient de l'arénite lithique au wacke et au schiste. les caractéristiques des éléments majeurs et traces correspondent à une sédimentation dans une marge continentale

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active, à des bassins associés à des arcs insulaires ou très probablement à une marge continentale passive comportant des roches volcaniques dans la région d'origine. Les compositions chimiques affichent une abondance sporadique, mais généralement grandissante des éléments lithophiles comme le La et le Th selon la position stratigraphique. Les valeurs epsilon $_{Nd(t)}$ deviennent de plus en plus négatives en allant vers le haut de la section et les âges du modèle mantellique épuisé deviennent de plus en plus avancés. Les données sont conformes à un mélange accru entre des sédiments en provenance de sources crustales supérieures du Mésoprotérozoïque et des sédiments provenant d'un arc magmatique. De telles données correspondent aux configurations du zircon détritique publiées faisant état de quantités croissantes de zircon d'environ 2 Ga ainsi qu'avec une région d'origine comprenant un arc volcanique panafricain (800 à 540 Ma) ou un magmatisme de marge active et une croûte principalement éburnéenne, très probablement dans le craton d'Afrique occidentale.

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INTRODUCTION

Meguma is the most outboard terrane in the northern Appalachian orogen, exposed on land only in Nova Scotia south of the Cobequid–Chedabucto fault zone (Fig. 1, inset). It is characterized by a thick succession of Cambrian to lower Ordovician metasedimentary rocks (Goldenville and Halifax groups), overlain along the northwestern margin by localized areas of Silurian to lower Devonian metavolcanic and metasedimentary rocks of the Rockville Notch Group (e.g., Waldron *et al.* 2009; White *et al.* 2018 and references therein). These stratified units are intruded by voluminous mainly Middle to Late Devonian granitoid rocks dominated by the South Mountain Batholith, and overlain unconformably by upper Paleozoic and lower Mesozoic sedimentary and volcanic rocks (Fig. 1).

White (2010, 2013) divided the Goldenville and Halifax formations in the southwestern part of the Meguma terrane

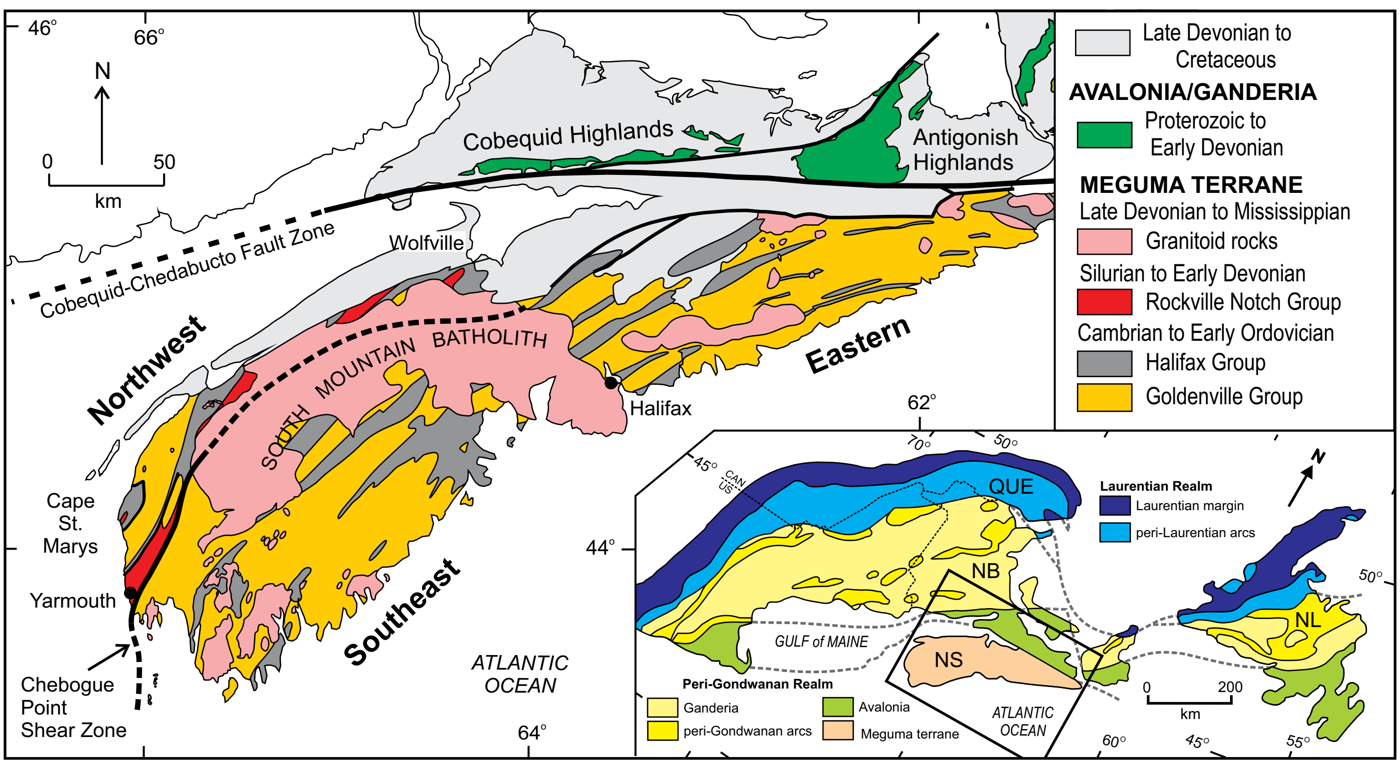

Figure 1. Simplified geological map of the Meguma terrane after White (2010) with inset map showing its location in the northern Appalachian orogen after Hibbard *et al.* (2006). Abbreviations: NB, New Brunswick; NL, Newfoundland; NS, Nova Scotia; QUE, Quebec.

into mappable formations (Fig. 2), thus elevating the former formations to Goldenville and Halifax groups and the former Meguma Group to Supergroup. Because of the possibility of confusion where the word Meguma has two meanings, in this paper we use the term Meguma only to refer to the terrane, and do not refer to the supergroup. In combination with the mapping and definition of formations, age constraints were provided by studies of trace and microfossils (White *et al.* 2012; Gingras *et al.* 2011), $^{40}Ar/^{39}Ar$ dating of detrital and metamorphic muscovite (Reynolds *et al.* 2012), and U–Pb dating of detrital zircon (Waldron *et al.* 2009, 2011; Pothier *et al.* 2015; Henderson 2016). The new stratigraphic framework also facilitated investigation of variations with time in characteristics such as sedimentary geochemistry, isotopic composition, and detrital zircon provenance (Waldron *et al.* 2009; White and Barr 2010), and interpretation of possible stratigraphic constraints on gold mineralization (White and Barr 2012a, b).

Those studies focused on the southwestern part of the Meguma terrane and included few data from the eastern half of the terrane because of lack in that area of systematic regional mapping and stratigraphic information, except in localized areas (Henderson 1986; Hill 1991; Ryan *et al.* 1996; Horne and Pelley 2007; White and Scallion 2011). However, recent mapping in the eastern Meguma terrane has resulted in a new bedrock geology map (Fig. 3) and revised stratigraphy (White and Vaccaro 2019, 2020; White and Nickerson 2021). Hence, the purpose of this paper is to present a revised assessment of variations in whole-rock chemistry, Sm–Nd isotopic composition, and detrital zircon signatures in the Meguma terrane that incorporates the new understanding of stratigraphy in the eastern part of the terrane. We present whole-rock chemical and Sm–Nd isotopic analyses for 22 samples from both the southwestern and eastern parts of the Meguma terrane which, in combination with previous data, provide better constraints on chemical variations with stratigraphy.

GEOLOGICAL SETTING

The Meguma terrane is generally inferred to have originated as a lower Paleozoic continental margin of Gondwana, although its original position and underlying basement remain uncertain. It has been interpreted to have been adjacent to the West African craton during the Cambrian (e.g., Schenk 1971, 1981, 1991, 1995, 1997; Waldron *et al.* 2009; van Staal and Hatcher 2010; Letsch *et al.* 2018; van Staal *et al.* 2021a, b), although other workers have included the Meguma terrane in Avalonia and/or interpreted it to have formed as a continental margin succession on Avalonia (e.g., Murphy *et al.* 2004; Romer *et al.* 2011). During opening of the Rheic Ocean, Meguma was one of several terranes or terrane assemblages that separated from Gondwana and eventually accreted to composite Laurentia, although the details of its journey remain unclear (e.g., Nance *et al.* 2010; Murphy *et al.* 2011; van Staal and Barr 2012; van Staal *et al.* 2021a, b; Warsame *et al.* 2021).

The Goldenville and Halifax groups have been interpreted as turbiditic continental rise and/or slope deposits (Schenk 1971, 1981, 1991, 1995, 1997; Waldron and Jensen 1985; Waldron 1992). They are unconformably overlain by a thinner sequence of early Silurian to Early Devonian slate, quartzite, and metavolcanic rocks of the Rockville Notch Group (White 2010, 2019; White and Barr 2012a, b, 2017; White *et al.* 2018). All these rocks were deformed into regional-scale upright shallow north- and south-plunging folds with well-developed north-striking steep axial-planar foliation (e.g., Culshaw and Lee 2006) and regionally metamorphosed at grades varying from lower greenschist- to upper amphibolite-facies between 406 and 388 Ma (Muecke *et al.* 1988; Raeside and Jamieson 1992; Hicks *et al.* 1999; Reynolds *et al.* 2012; White and Barr 2012a, b). They were also intruded by numerous, late syn- to post-tectonic, mainly Middle to Late Devonian, peraluminous granitic plutons (e.g., Clarke *et al.* 1997, 2000; Bickerton *et al.* 2022). Deformation, regional metamorphism, and plutonism were associated with a Middle to Late Devonian orogenic event that has been traditionally called the Acadian orogeny. However, the main events of the Acadian orogeny are interpreted to have been associated with late Silurian-Early Devonian accretion of Avalonia to the composite margin of Ganderia and Laurentia (Hibbard *et al.* 2007; van Staal and Barr 2012, van Staal *et al.* 2021a, b), a model which does not readily accommodate younger events in the Meguma terrane outboard of Avalonia. Alternatively, in recognition of its younger age, the orogenic event in Meguma also has been termed Neoacadian, but that term is also inappropriate because it refers to a Late Devonian to Early Carboniferous event in New England (Robinson *et al.* 1998), also far inboard of the Meguma terrane. Hence, to emphasize its unique character and timing, we here introduce the term Kejimkujik orogeny for the Middle Devonian orogenic event in Meguma to distinguish it from the more inboard older Acadian and younger Neoacadian events. Subsequent Carboniferous motion on the Cobequid–Chedabucto fault zone and renewed transpression throughout the Meguma terrane (e.g., Culshaw and Leisa 1997; Culshaw and Reynolds 1997) was likely related to docking of Gondwana (Africa) outboard of the Meguma terrane before and during the Alleghanian orogeny (Murphy *et al.* 2011; van Staal and Barr 2012; White and Barr 2012a, b).

Waldron *et al.* (2011) noted similarities in the Cambrian to Tremadocian lithological successions of the Meguma terrane and the Harlech Dome of North Wales, including the presence of Cambrian Series 3 (Miaolingian) manganese-rich sedimentary rocks. They proposed that both Meguma and North Wales were part of the Megumia

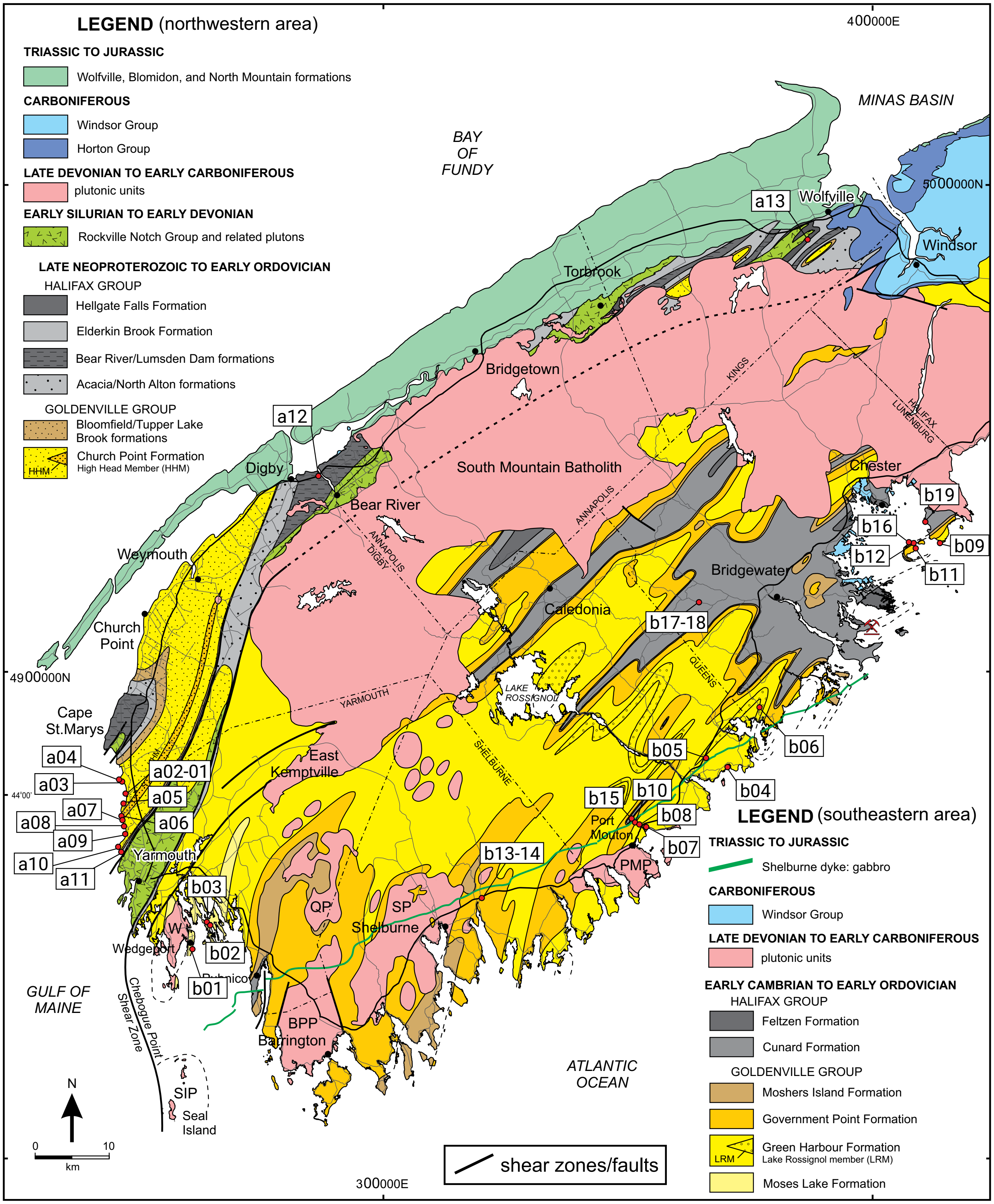

Figure 2. Geological map of the northwestern and southeastern parts of the Meguma terrane after White (2013) and White and Barr (2012b). Locations of samples a01 to a13 and b01 to b19 are shown; UTM for sample locations are listed in Table A1. Pluton abbreviations: BPP, Barrington Passage, PMP, Port Mouton; QP, Quinan; SP, Shelburne; SIP, Seal Island; W, Wedgeport.

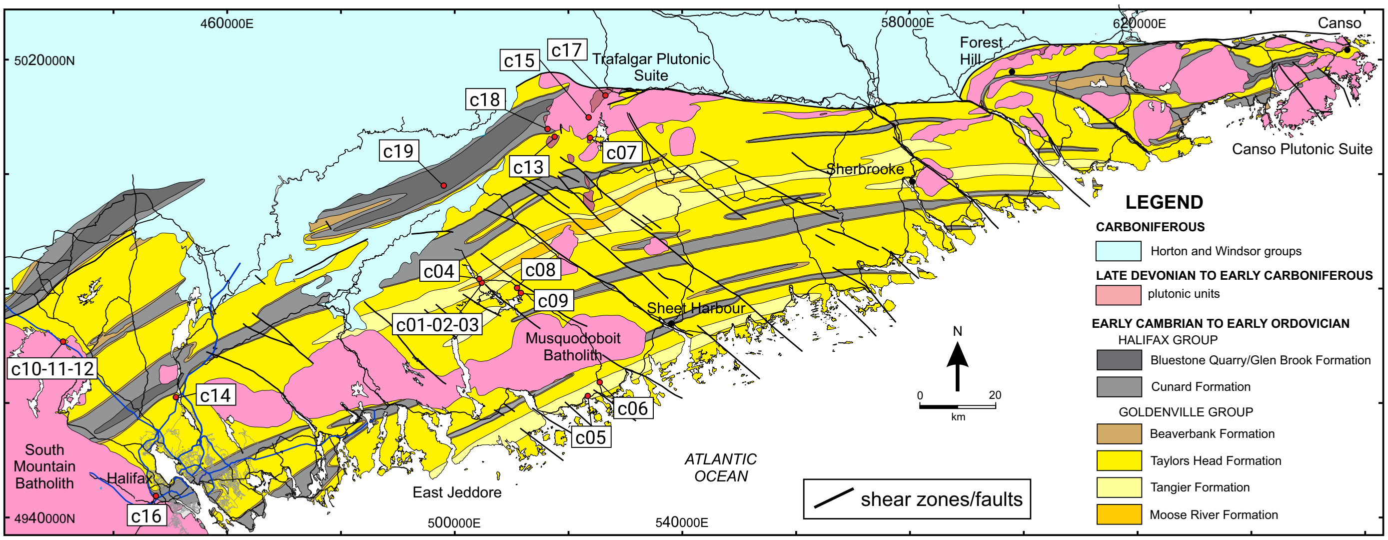

Figure 3. New geological map of the eastern Meguma terrane after White and Nickerson (2021) and unpublished data. Locations of samples c01 to c13 are shown; UTM for sample locations are listed in Table A1.

domain that occupied a rift at the margin of Gondwana in the early Paleozoic. Acritarch data (White *et al.* 2012) suggest that deposition continued in the Halifax Group at a time when rocks of the Harlech Dome were being uplifted and eroded and the Meguma terrane lacks evidence for the Ordovician volcanism present in North Wales, so if these areas were contiguous in the Cambrian, their histories diverged in the Ordovician (Pothier *et al.* 2015).

STRATIGRAPHY OF THE GOLDENVILLE AND HALIFAX GROUPS

The Chebogue Point shear zone and South Mountain Batholith are used to divide the Meguma terrane into three areas here termed northwestern (NW), southeastern (SE), and eastern (E) (Fig. 1). The lithologically distinctive and typically manganiferous beds of the correlative Bloomfield, Tupper Lake Brook, Moshers Island, and Beaver Bank formations provide a marker horizon at ca. 500 Ma throughout the terrane and were assigned to the uppermost Goldenville Group by White (2010). The underlying units have broad similarities but differ in detail among the NW, SE, and E areas of the terrane (Fig. 4). The thickest unit is the Church Point Formation in the NW area, with an estimated stratigraphic thickness of about 7.8 km, although the base is not exposed (Fig. 4). The oldest rocks of the formation occur in the core of an anticline on the coast between Yarmouth and Cape St. Mary (Fig. 2), from which U–Pb detrital zircon data suggest a maximum depositional age of about 540 Ma with large errors (Waldron *et al.* 2009; Henderson 2016). In the area southeast of the Cheborgue Point shear zone, the rocks that appear to be laterally age-equivalent to the Church Point Formation are subdivided into three formations (Moses Lake, Green Harbour, and Government Point).

In the eastern area of the terrane, the most extensive unit is the Taylors Head Formation (Fig. 3), with lithological similarities and similar stratigraphic thickness to the Government Point Formation (Fig. 4). Based on this correlation, the underlying Tangier and Moose River formations are interpreted to be laterally equivalent to the upper part of the Green Harbour Formation (Fig. 4).

The manganiferous Bloomfield, Tupper Lake Brook, Moshers Island, and Beaver Bank formations are overlain by sulphidic slate, metasiltstone, and metasandstone of the lowermost formation of the Halifax Group, named Acacia Brook and North Alton formations in the NW area and Cunard Formation in the SE and E (Fig. 4). The overlying Bear River, Lumsden Dam, Feltzen, and Glen Brook/Bluestone Quarry formations are interpreted to be age equivalent because of lithological similarity and the presence in most of Lower Ordovician fossils (White *et al.* 2012). The youngest units of the Halifax Group (Elderkin Brook and Hells Gate Falls) outcrop only in the Wolfville area (Fig. 2) where fossils indicate a minimum age of late Floian (ca. 470 Ma).

SAMPLE DISTRIBUTION AND ANALYTICAL METHODS

For this study, twenty-two samples were collected for Sm–Nd isotopic analysis to provide increased coverage throughout the terrane when combined with data from 13 samples reported by Waldron *et al.* (2009) and 16 samples compiled from Clarke and Halliday (1985), Clarke *et al.* (1988, 1993), and Currie *et al.* (1998). The stratigraphic

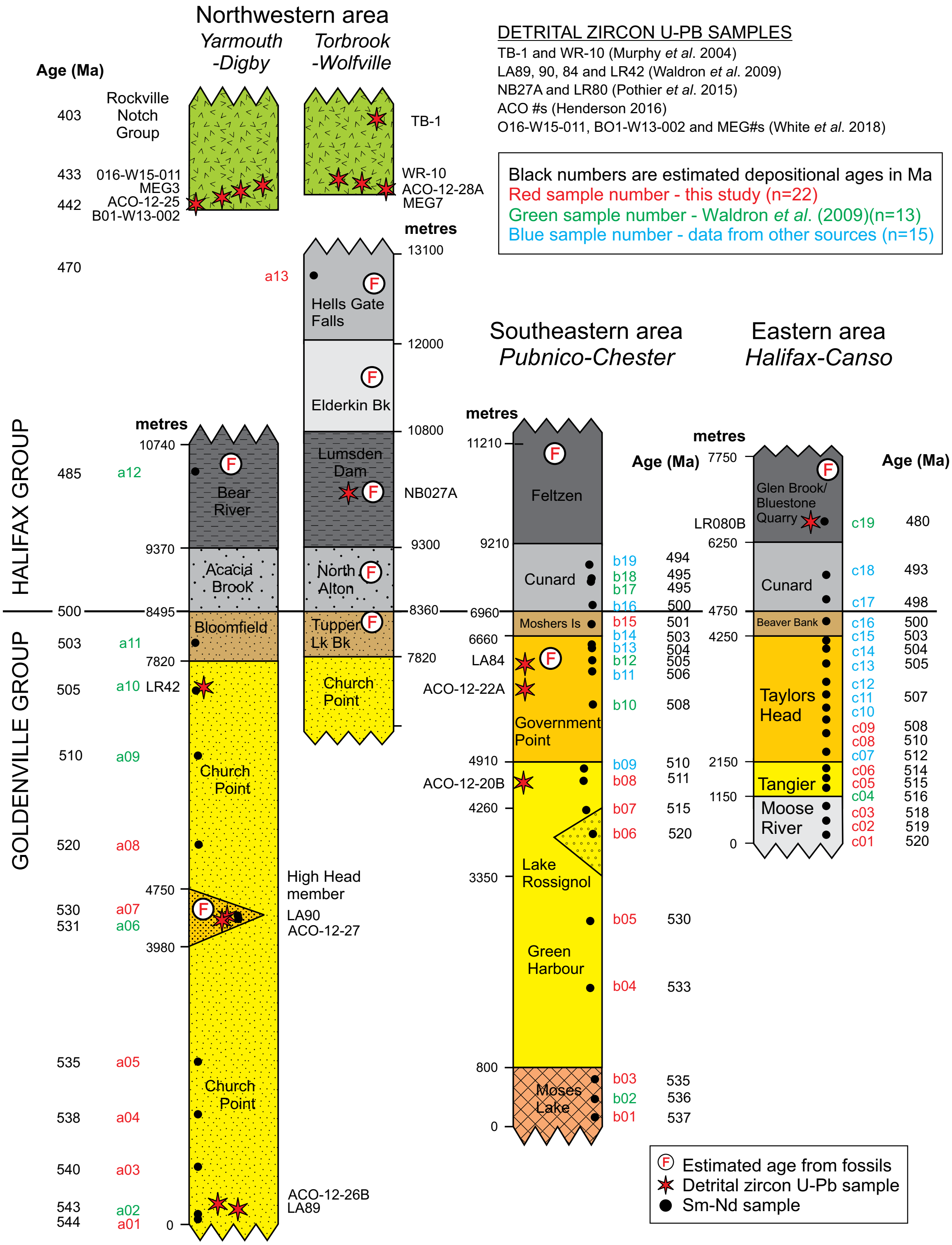

Figure 4. Simplified stratigraphic columns for the northwestern, southeastern, and eastern areas of the Meguma terrane showing sample positions (black circles). Stratigraphic units are from White (2010), Pothier *et al.* (2015), and C. White (unpublished) are labelled and coloured similar to Figures 2 and 3. Stratigraphic thickness estimates and sample depositional ages are based on maps in Figures 2 and 3 and cited U–Pb data. Fossil occurrences are from White *et al.* (2012), Pratt and Waldron (1991), and Cumming (1985). Sm–Nd data sources are from this study and Waldron *et al.* (2009), Clarke and Halliday (1985), Clarke *et al.* (1988, 1993), and Currie *et al.* (1998), as tabulated in Table A1.

positions and ages of the samples (Fig. 4) were estimated from field relations and locations on the new maps of the Meguma terrane (Figs. 2, 3). Locations for the published samples are constrained as much as possible based on information provided in the original papers. In addition to the isotopic data, whole-rock chemical data are available for most of the samples, as well as petrographic information for samples from the present study and Waldron *et al.* (2009). Whole-rock chemical analyses for samples from this study were done by Bureau Veritas Laboratory, Vancouver, BC. Major elements were analyzed by X-ray fluorescence after $LiBO_2$ fusion and rare earth and refractory elements by Inductively Coupled Plasma - Mass Spectrometry (ICP-MS) following lithium metaborate/tetraborate fusion and nitric acid digestion or Aqua Regia digestion. The data are listed in Supplementary data Table S1 (see footnote 1), in combination with chemical data compiled from the sources of the isotopic data where available. The new Sm–Nd isotopic analyses were done at the Université Blaise Pascal, Clermont-Ferrand, France, following techniques adapted from those described by Pin and Santos (1997) and LeFèvre and Pin (2002). The samples were decomposed by fusion with a $LiBO_2$ flux at ca. 1150°C in an induction furnace and the resulting melt was quenched in 1.25M HCl, after addition of a mixed ^{149}Sm–^{150}Nd-enriched tracer. Then, a fraction containing the LREE was separated from most other elements by cation exchange chromatography. This LREE fraction was further purified by extraction chromatography on a micro-column filled with TRU resin (Eichrom). Then, Nd and Sm suitable for mass spectrometry were isolated from lighter lanthanides and from each other by using another extraction chromatography column filled with Ln resin (Eichrom) and operated on-line downstream of the TRU micro-column. The Sm concentrations were determined by isotope dilution thermal ionization mass spectrometry (ID-TIMS) with an upgraded, fully automated VG54E instrument, with sample loaded in a drop of phosphoric acid on a single tantalum filament. The ^{143}Nd/^{144}Nd isotope ratios (and ^{150}Nd/^{144}Nd ratios allowing determination of the Nd concentrations by isotope dilution) were measured with a Triton mass spectrometer operated in static multicollection mode at Laboratoire GIS, Université de Nîmes, with Nd loaded on a double rhenium filament assembly. The ^{143}Nd/^{144}Nd ratios are given relative to a value of 0.512110 for the JNdi-1 isotopic standard (Tanaka *et al.* 2000), and the precision of ^{147}Sm/^{144}Nd ratios is ± 0.2%. The new isotopic data are listed in Appendix Table A1, together with a compilation of other published data, listed in inferred stratigraphic order with estimated age in each of the NW, SE, and E areas.

[1]Supplemental Data. Table S1. Please visit https://journals.lib.unb.ca/index.php/ag/article/view/32794/1882528212 to access the supplementary material

PETROGRAPHY

Metamorphic grade varies widely over the Meguma terrane as a result of both regional and contact metamorphism (e.g., Raeside and Jamieson 1992; Mahoney 1996; White and Barr 2012a, b). Samples analyzed in this study are in the greenschist facies (chlorite and biotite zones), although some data compiled from previous work are from higher grade samples. Based mainly on grain size and abundance of quartz relative to other minerals, the samples range from pelitic to psammitic. Overall, the proportion of finer (pelitic and semi-pelitic) material increases up-section in the Goldenville and Halifax groups and, overall, the Halifax Group is finer grained and more pelitic than the Goldenville Group. Our study focussed on the coarser-grained semi-pelitic and psammitic samples in both groups, and hence pelitic rocks are less well represented in the dataset. Petrographic features show little variation throughout the stratigraphy in all three areas, except that the three lowermost psammitic samples in the Church Point Formation in the northwestern area (Fig. 2) lack detrital muscovite.

In general, psammitic samples retain more clastic-looking textures and are less recrystallized than the pelitic and semi-pelitic samples, but all samples are metamorphosed and original sedimentary features such as laminae which are readily visible in hand sample are obscured by new mineral growth when viewed in thin section. In the psammitic samples, the original clay matrix has been recrystallized to sericite, chlorite, and epidote, but sand-sized detrital grains appear little affected. Such grains include quartz, Na-rich plagioclase, muscovite, zircon, tourmaline, and opaque grains. Most psammitic samples have more than 5% matrix and are classified as feldspathic wacke to quartz wacke (classification of Boggs 2001).

Detrital muscovite is a prominent component of psammitic samples throughout the Goldenville and Halifax groups, except near the base of the section in the NW area, but no biotite of detrital origin was observed. Single-grain ^{40}Ar/^{39}Ar dating of detrital muscovite in the Meguma terrane by Reynolds *et al.* (2012) showed evidence for a Mesoproterozoic source, interpreted to be the Amazonian craton, but the nature of the source — metamorphic or igneous — was not indicated by the chemical characteristics of the muscovite. Most of the analyzed muscovite grains show evidence of late Neoproterozoic to early Cambrian resetting just prior to sediment deposition, interpreted by Reynolds *et al.* (2012) to be consistent with rapid uplift associated with a rifting environment.

WHOLE-ROCK CHEMISTRY

White and Barr (2010) presented a detailed assessment of the whole-rock chemical variations in the NW and SE areas of the Meguma terrane; here we restrict our discussion to data from 43 samples from which we also have Sm–Nd isotopic data; the remaining 8 samples with Sm–Nd data lack whole-rock chemical data. Samples with chemical data include 18 from the eastern area of the terrane that was not covered in the study by White and Barr (2010), and a subset of about 30 samples from throughout the terrane which includes trace elements such as La and Sc that were not available in the dataset utilized by White and Barr (2010).

Overall, the samples display an increase in SiO_2 content from ~44% in pelitic samples to close to 80% in the most quartz-rich psammitic samples (Fig. 5a). None of the analyzed samples from the SE area has SiO_2 content less than 55%, but otherwise all 3 areas contain similar ranges of sample compositions. Loss-on-ignition varies from less than 1% in high SiO_2 samples to more than 6% in some lower SiO_2 samples (Fig. 5a). Hence, to facilitate comparisons, the analyses were recalculated to total 100% excluding loss-on-ignition before plotting on Figures 5b, c, d and 6a.

On a chemical classification diagram using ratios of Fe_2O_3/K_2O and SiO_2/Al_2O_3 (Fig. 5b), the samples lie mainly in the shale, wacke, and lithic arenite fields, with a few plotting in the high-iron shale/sandstone fields. None of the samples are close to the quartz arenite field, consistent with maximum SiO_2 contents of ~80% and the results of White and Barr (2010) from a much larger data set (~600 samples) from the NW and SE areas. On the plot of molar Al_2O_3/Al_2O_3+ CaO+Na_2O+ K_2O (Chemical Index of Alteration or CIA; Nesbitt and Young 1982) against SiO_2 (Fig. 5c) the lower SiO_2 samples generally display higher CIA than the higher SiO_2 samples. In the CIA calculation for Figure 5c, corrections were made for CaO included in apatite and carbonate minerals, following McLennan (1993) so that the CIA reflects mainly weathering of silicate minerals. According to McLennan (1993), CIA values of about 45 to 55 indicate virtually no weathering, whereas values close to 100 indicate intense weathering with complete removal of alkali and alkaline earth elements. In general, samples from the Goldenville and Halifax groups with higher SiO_2 (more quartz) have lower CIA than the lower SiO_2 samples. Most of the pelitic and semi-pelitic samples fall in the intermediate stage of silicate weathering (CIA 60–80), close to the mean CIA value of 72 for suspended (fine-grained) sediment in 44 modern rivers reported by Li and Yang (2010). These data are interpreted to indicate that the sediments that formed the Goldenville and Halifax groups were moderately weathered or reworked sediments.

On the tectonic setting discrimination diagram using K_2O/Na_2O ratio and SiO_2 (Fig. 6a), most samples plot in the active continental margin field, consistent with the results from the larger dataset of White and Barr (2010). However, on a Th-La diagram, the majority of samples plot in the field for island arcs with continental crust, rather than in the combined active and passive continental

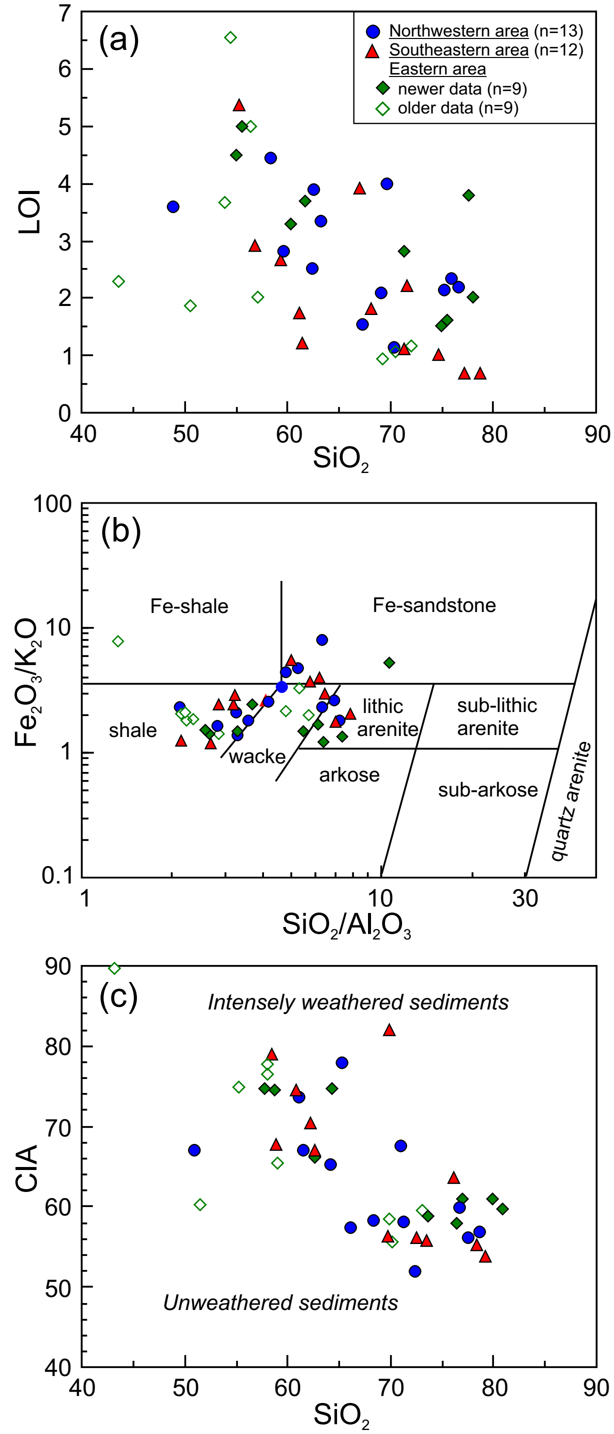

Figure 5. Diagrams illustrating whole-rock chemical characteristics using data from Supplementary Data Table S1. (a) Loss-on-ignition (LOI) plotted against SiO_2. (b) Fe_2O_3/K_2O vs SiO_2/Al_2O_3 with fields from Herron (1988). (c) Chemical Index of Alteration (CIA) of Nesbitt and Young (1982) against SiO_2. CIA is molar Al_2O_3/(Al_2O_3+CaO+Na_2O+K_2O), with CaO corrected for P_2O_5 and carbonate minerals following McLennan (1993).

margin field (Fig. 6b). Scatter to higher La values outside the defined continental island arc field is common in samples from the NW and SE areas, whereas the samples from the eastern area plot mainly in the that field. A similar result is shown by a diagram using ratios of Ti/Zr and La/Sc, with samples from the NW and SE areas showing wider range in La/Sc ratios at high Ti/Zr and plotting outside the defined field (Fig. 6c). Less scatter is displayed in the Th-Sc-Zr ternary diagram and almost all samples plot in the continental island arc field (Fig. 6d). Hence, overall, these data support the conclusion of White and Barr (2010) that the chemical characteristics of the Goldenville and Halifax groups are not consistent with a source that provided compositionally mature sediments but were more likely derived from a source area that included volcanic material.

In their study of mainly major element chemical data for samples from the NW and SE parts of the Meguma terrane, White and Barr (2010) did not detect systematic changes in composition with stratigraphic position through the Goldenville and Halifax groups, suggesting that provenance did not change significantly over time. However, results from this study suggest that some trace elements and trace element ratios do show such variations. For example, using estimated age as an approximate measure of stratigraphic position, plots of age against La, Th, and La/Sc and Th/Sc, although scattered, all tend to increase up section (Fig. 7a–d).

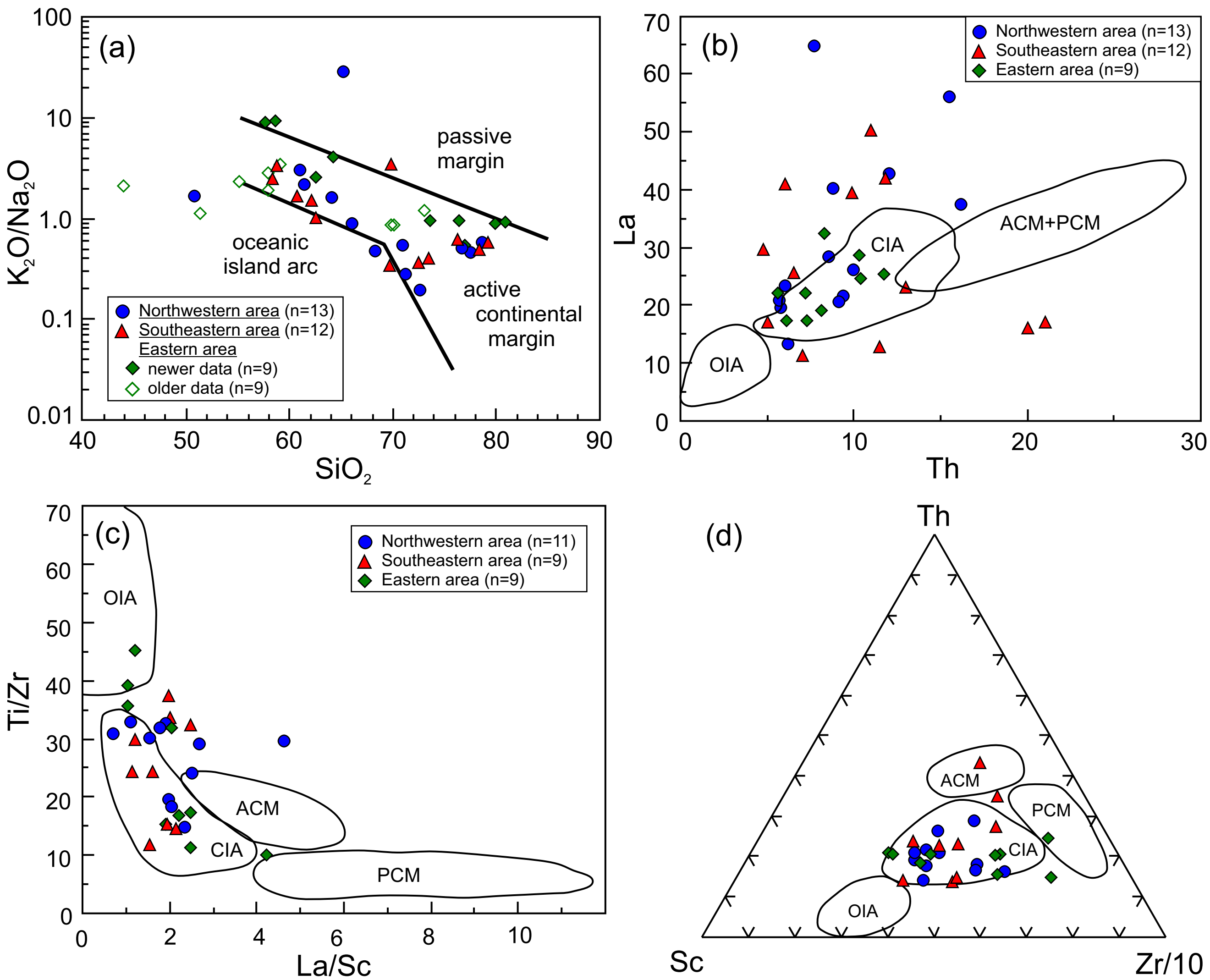

Figure 6. Tectonic setting discrimination diagrams for sedimentary rocks. (a) K_2O/Na_2O against SiO_2 with fields from Roser and Korsch (1986). (b) La against Th. (c) Ti/Zr against La/Sc. (d) Ternary Th-Sc-Zr/10 diagram. Fields in (b), (c), and (d) are from Bhatia and Crook (1986) for greywacke samples deposited in various tectonic settings: ACM, active continental margin; CIA, continental island arc; OIA, oceanic island arc; PCM, passive continental margin.

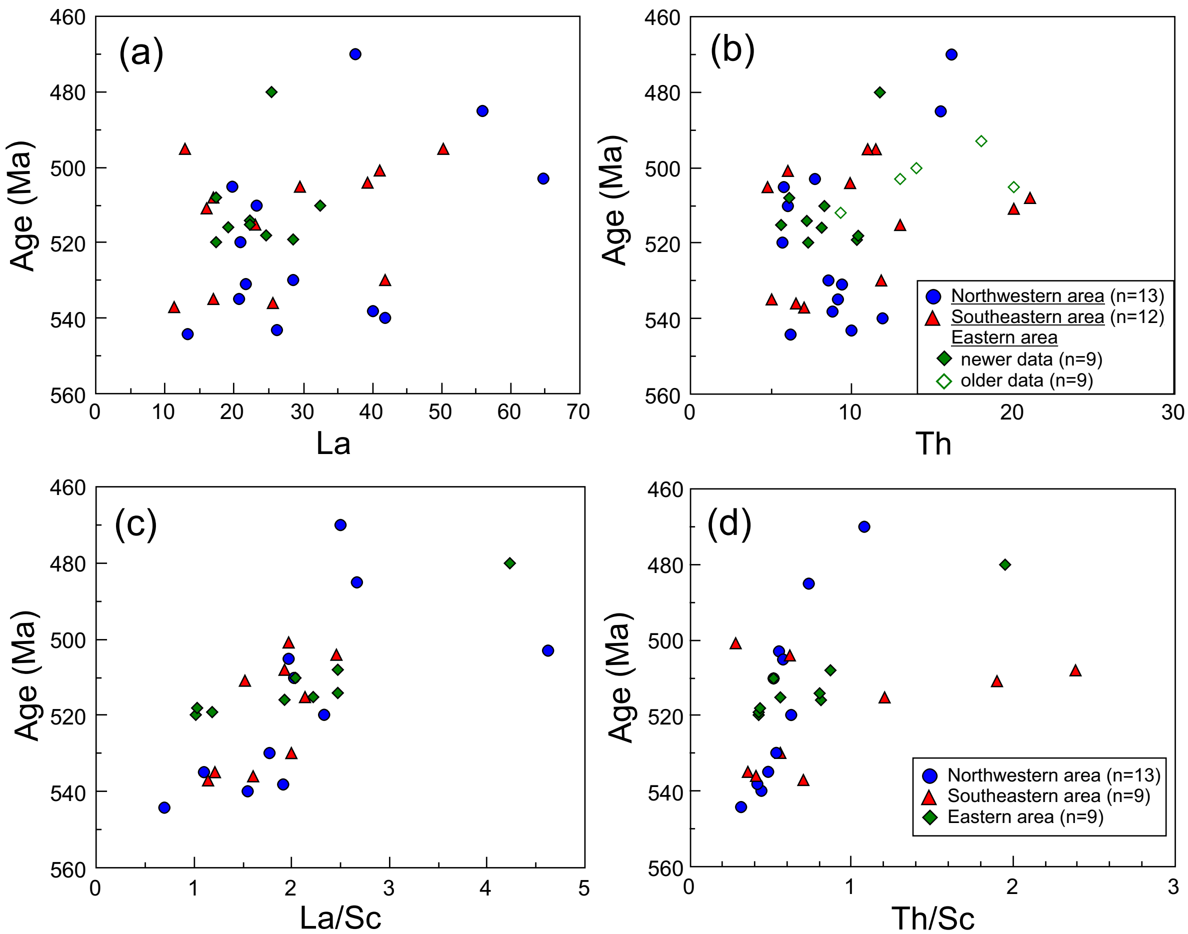

Figure 7. Plots of estimated sample age against (a) La, (b) Th, (c) La/Sc, and Th/Sc. Legend in (a) is the same as in (b) except no La data are available for older samples from the Eastern area. Legend in (c) is the same as in (d).

Sm-Nd ISOTOPIC COMPOSITIONS

Samples with estimated depositional ages between about 530 Ma and 544 Ma occur only in the NW and SE areas (Fig. 4). The $\varepsilon_{Nd(t)}$ numbers for those samples show a wide range from +0.89 to −6.67 (Fig. 8a). Although the overall pattern is obscured by three outlying samples b02, b03, and a06 which have positive $\varepsilon_{Nd(t)}$, the remaining samples older than ~530 Ma, although scattered, display a trend of increasingly negative $\varepsilon_{Nd(t)}$ with decreasing age. Among the younger samples (<530 Ma), including those from the eastern area where the stratigraphically lowest samples are estimated to have an age of ~520 Ma (Fig. 4), the $\varepsilon_{Nd(t)}$ ranges from -3 to -9.96, and a scattered trend of increasingly negative numbers with decreasing age is similarly present (Fig. 8a).

The corresponding plot of depleted mantle model ages against age also shows wide range, especially in the samples estimated to have an age of ~530 Ma or older, where T_{DM} varies 1.20 Ga to 1.86 (Fig. 8b). Among the younger samples (<530 Ma), the range in T_{DM} is similar (1.63 to 2.22 Ga). Depleted-mantle model ages in sedimentary rock have no geological significance and represent an average of all the components in the source (e.g., Arndt and Goldstein 1987). However, the data indicate that the sedimentary rocks contain increasing amounts of older, more evolved components with decreasing age, as also noted by Waldron *et al.* (2009) in a smaller subset of these data. The trend is also apparent on an expanded-scale plot of $\varepsilon_{Nd(t)}$ against age showing the Meguma terrane data in comparison with isotopic evolution of depleted mantle (DePaolo 1981) and various crustal units through time (Fig. 9a). Fields are shown for evolution of Neoproterozoic Pan-African granite and metamorphic rocks and Eburnean metamorphic rocks in Cameroon from Toteu *et al.* (2001), and for Amazonian Mesoproterozoic crust from Santos *et al.* (2008). Meguma terrane samples become increasingly negative with decreasing age, as is apparent in the curve in the sample data (Fig. 9a) that is consistent with an

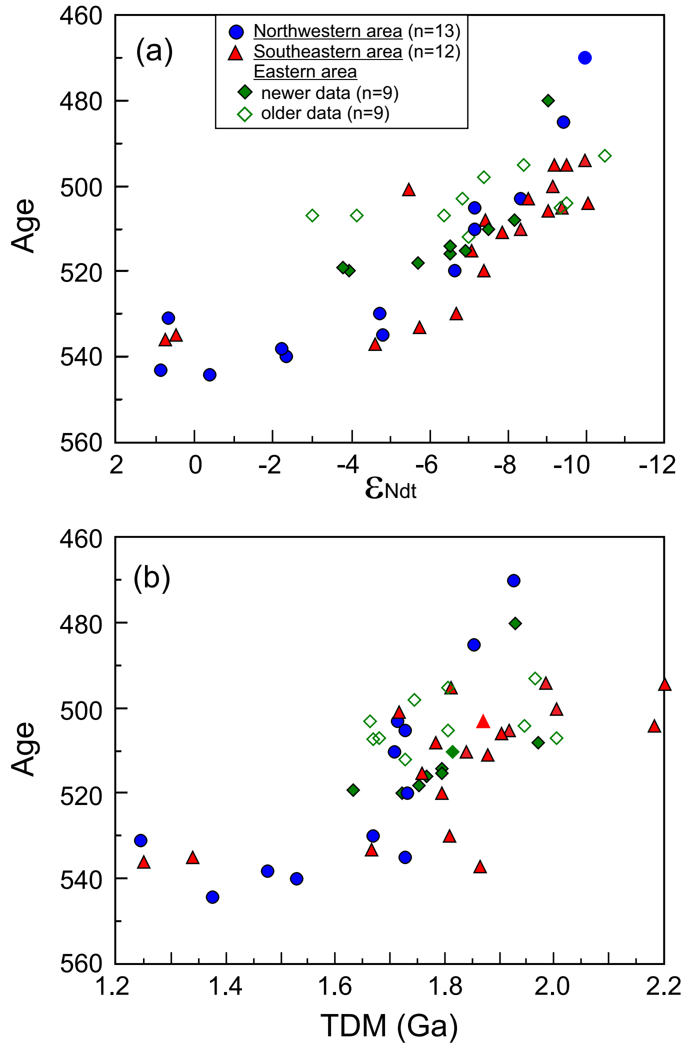

Figure 8. Plots of (a) $\varepsilon_{Nd(t)}$ against estimated depositional age and (b) depleted mantle model age against estimated depositional age from Figure 4. Isotopic data for the Goldenville and Halifax groups are from Table A1.

increasing proportion of older (Mesoproterozoic) sediment. The pattern in the Meguma terrane samples is similar to that in the Cameroon Pan-African samples. The Pan-African field is similarly interpreted to be a result of mixing between relatively juvenile and older, more evolved sources (Toteu *et al.* 2001). However, unlike the Cameroon Pan-African samples, the sources for the Meguma terrane samples do not extend to ages as old as the Paleoproterozoic (Eburnean) sources for the Pan-African field (Fig. 9a). The mixing model is supported further by a plot of $\varepsilon_{Nd(t)}$ against Th/Sc ratio on which the samples fall on the mixing line between average island-arc andesite and average upper continental crust (Fig. 9b). They also plot in the field for deep-sea turbidites of both quartzose and non-quartzose composition deposited at active continental margins from McLennan *et al.* (1990). McLennan *et al.* (1990) interpreted these samples to reflect variable mixtures of younger arc-derived detritus and older upper continental crust sources. Unlike the deep-sea turbidite samples, the Meguma terrane samples do not show evidence for the involvement of older (Paleoproterozoic) crust, consistent with the data shown in Figure 9a.

DETRITAL ZIRCON AGES

As shown by earlier work (e.g., Waldron *et al.* 2009; Pothier *et al.* 2015) additional evidence for increasing contribution of older crust with time in the sediment sources for the Goldenville and Halifax groups is provided by the detrital zircon age spectra (Fig. 10). Although no new detrital zircon data were obtained in this study, additional data from Henderson (2016) and White *et al.* (2018) have been added which were not available for the compilations by Waldron *et al.* (2009) and Pothier *et al.* (2015). Two additional spectra from the NW area from Henderson (2016), one from the lowermost part of the Church Point Formation (Fig. 10a) and one from the High Head member (Fig. 10c), confirm the results from those areas reported by Waldron *et al.* (2009). The samples contain almost entirely Neoproterozoic zircon grains with peaks in the Cryogenian and Ediacaran. Taking errors into account, the maximum depositional ages of 579 ± 7 Ma and 551 ± 8 Ma interpreted by Henderson (2016) are similar to those of Waldron *et al.* (2009) at 544 ± 18 Ma and 529 ± 19 Ma, respectively.

The spectrum obtained by Henderson (2016) for a sample from the Green Harbour Formation (Fig. 10e) is especially significant because it is the stratigraphically lowermost detrital zircon sample available from the SE area (Fig. 4). The spectrum includes the abundant Cryogenian and Ediacaran peaks seen in the older samples from the Church Point Formation but also includes a Tonian peak at 860 Ma and a Paleoproterozoic peak at ~2080 Ma (Fig. 10e). A similar Paleoproterozoic peak is seen in the sample from the upper part of the Church Point Formation in the NW area (Fig. 10f).

Henderson (2016) also reported an age spectrum from a sample from the Government Point Formation in the SE area (Fig. 10g), with results similar to those in a somewhat younger sample (Fig. 10h) reported by Waldron *et al.* (2009) but with more resolution of Paleoproterozoic (2075 Ma) and Tonian (881 Ma) and Cryogenian-Ediacaran peaks. She interpreted a maximum depositional age of 535 ± 5 Ma. Two samples from the overlying Halifax Group have similar signatures with more numerous Paleoproterozoic and Mesoproterozoic peaks (Fig. 10i, j).

The increased proportion of Paleoproterozoic and Mesoproterozoic zircon grains in these samples is consistent with the increasingly negative $\varepsilon_{Nd(t)}$ and older depleted mantle model ages (Fig. 8a, b) which

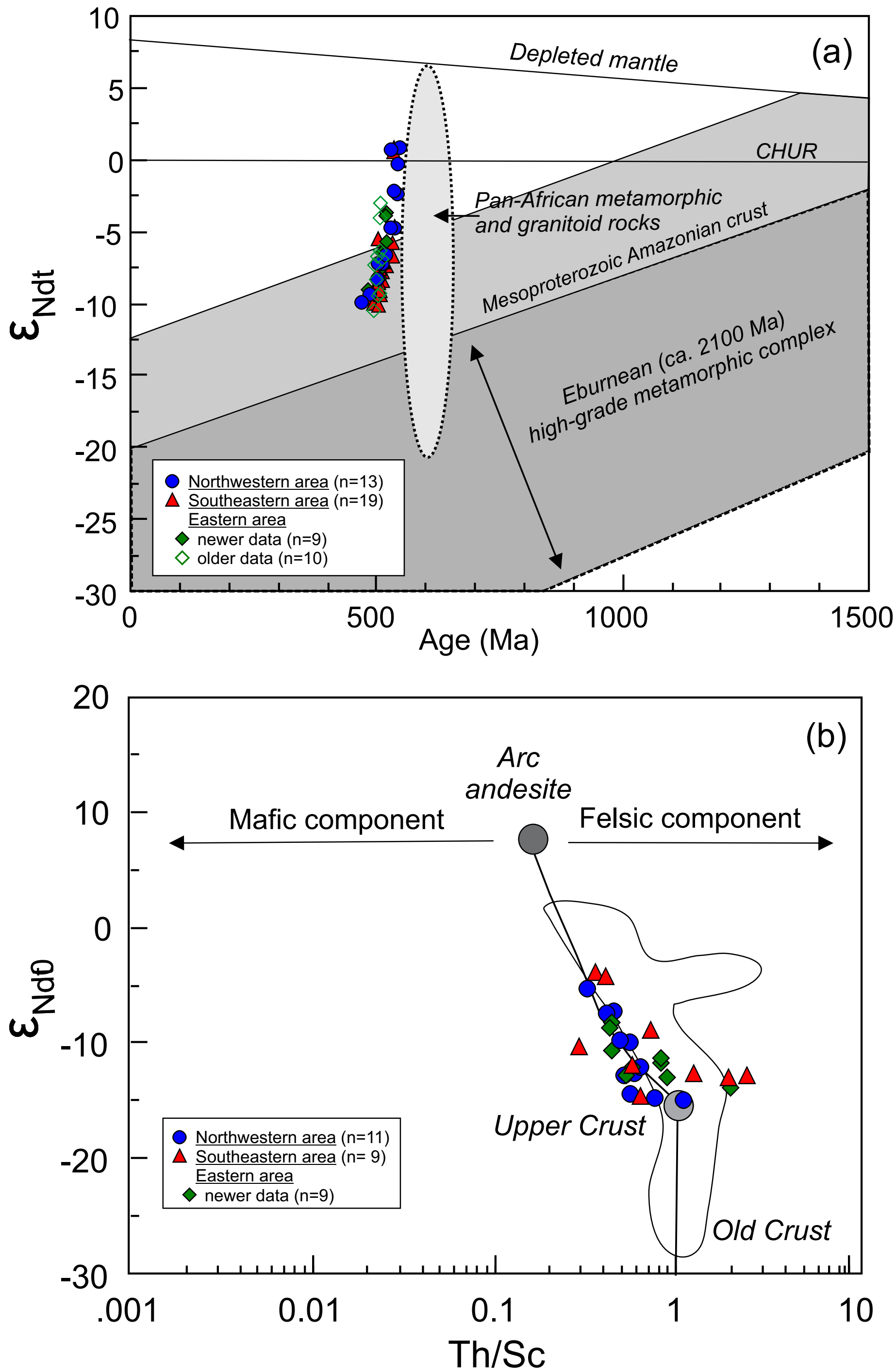

Figure 9. Plots of (a) $\varepsilon_{Nd(t)}$ against estimated depositional age and (b) $\varepsilon_{Nd(0)}$ against Th/Sc ratio. In (a) fields for Nd isotopic evolution are shown from Toteu *et al.* (2001) for Pan-African granite and metamorphic rocks and Eburnean high-grade metamorphic rocks from Cameroon. Mesoproterozoic Amazonian crust is from Santos *et al.* (2008). The depleted-mantle evolution curve is from the model of DePaolo *et al.* (1991). CHUR is chondrite uniform reservoir. Diagram (b) is after McLennan *et al.* (1990) and shows the field for deep-sea turbidites (both quartzose and non-quartzose) deposited at active continental margins and derived from variable mixtures of younger arc-derived detritus and older upper continental crust sources. Curved line shows mixing relationship between average island-arc andesite (dark grey circle) and upper continental crust (light grey circle). Meguma terrane samples follow that curve but do not show evidence for involvement of older crust, consistent with (a).

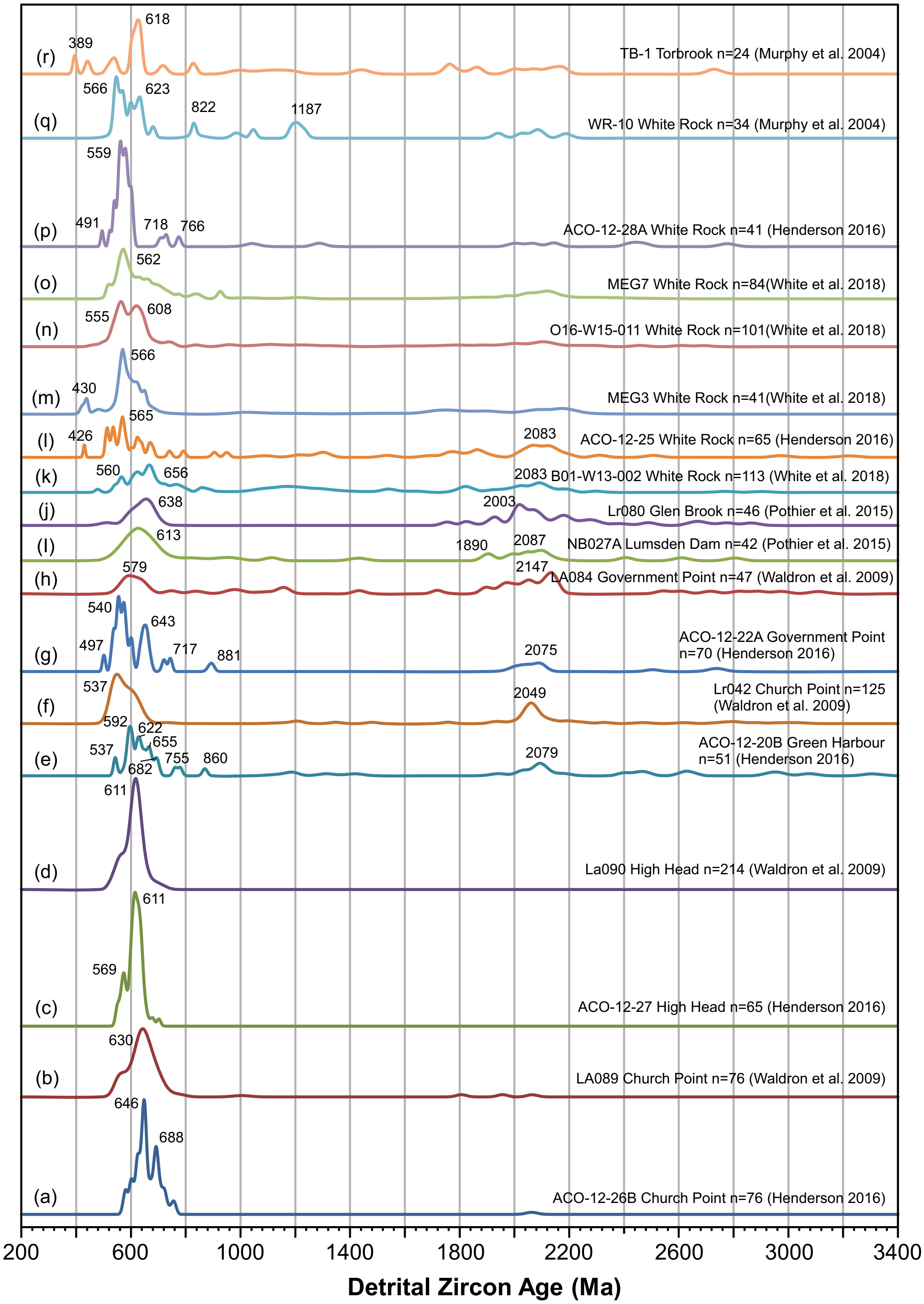

Figure 10. Compilation of normalized detrital zircon age probability plots for samples from the Goldenville and Halifax groups and overlying Rockville Notch Group arranged from oldest (a) to youngest (r). Stratigraphic positions and approximate inferred depositional ages of samples are shown on Figure 4. Reference to data source is indicated on each profile. Normalized age probability plots were constructed using the downloadable Excel file from Arizona Laser Chroncenter (2010). Data are normalized by the number of analyses used so that each curve contains the same area.

suggest increased contributions of older material during sediment deposition. These results corroborate the trends reported by Waldron *et al.* (2009) based on fewer detrital zircon spectra and on Sm–Nd data. Eight detrital zircon spectra from the overlying Rockville Notch Group are also shown in Figure 4 and show patterns similar to those in the underlying Halifax and upper Goldenville groups, with mainly Cryogenian and Ediacaran peaks and scattered older peaks (Fig. 10k–r). The "Eburnian" peak at 2000–2200 Ma in these profiles is generally interpreted to be consistent with West African provenance for Cambrian-Devonian sediments deposited in the Meguma terrane (e.g., Krogh and Keppie 1990; Waldron *et al.* 2009; White *et al.* 2018). That peak persists to the exposed base of the Goldenville Group in the NW area, but it is weak (Fig. 10a).

DISCUSSION

Deposition of the Goldenville and Halifax groups at an active continental margin, in basins within a Japan-type island arc with continental crust, or in a passive margin with volcanic rocks in the source area is suggested by the whole-rock and trace-element chemical data presented here. These environments differ from the classical view of deposition of the Goldenville and Halifax groups at a continental passive margin of sediment derived from a quartz-rich continental source (e.g., Schenk 1971, 1981, 1991, 1995, 1997; Keppie and Krogh 1990; Romer *et al.* 2011). However, it is consistent with the conclusion of White and Barr (2010) that the petrographic and chemical characteristics of the sediments are the result of derivation from Pan-African orogenic belts containing recycled sediments from older cratons as well as juvenile material from igneous units in those belts.

The increasingly evolved $\varepsilon_{Nd(t)}$ isotopic signatures recorded in the samples are consistent with the continued addition of sediment derived from older, more evolved crust, or less addition of juvenile material from Pan African magmatism. However, the detrital zircon populations show that Neoproterozoic sources were dominant throughout deposition of the Goldenville and Halifax groups and Rockville Notch Group. The abundance of Eburnean zircon reaches a maximum in the upper Goldenville and Halifax groups, and then diminishes through the deposition of the Rockville Notch Group. This change is consistent with a model proposed by MacDonald *et al.* (2002) that bimodal magmatism in the Rockville Notch Group is indicative of rifting of the Meguma terrane from Gondwana, the likely source of Eburnean zircon. The almost complete absence of Mesoproterozoic zircon in most age spectra suggests that Amazonia was not the source area and external detritus was derived from the West African craton. Although the most negative $\varepsilon_{Nd(t)}$ values and depleted mantle model ages suggest that sediment was derived from Mesoproterozoic crust, that interpretation is not supported by the detrital zircon spectra. Instead, the data suggest that the Mesoproterozoic model ages result from mixing of Paleoproterozoic and Neoproterozoic sources.

The evolutionary pattern could have resulted from erosion of a given crustal segment that progressively unroofed deeper and older levels, thereby generating an inverted stratigraphy in the resulting sedimentary basin (e.g., Ugidos *et al.* 2003). However, instead of vertical change, a lateral change of source is also likely to occur during the opening and evolution of a rift basin or rifted margin. The rift shoulders would be the major, relatively proximal contributors in the early stages, until removed by erosion and subsidence, thus allowing sediment transport from more distant and much more widespread sources located in the plate interior, through potentially extremely long river systems (e.g., Uguidos *et al.* 2003; Thomas *et al.* 2017).

Potential sources of sediment are numerous among the terranes that occurred at the periphery of the West African craton of Gondwana near Neoproterozoic-Cambrian transition. For example, Cadomia (e.g., Linnemann *et al.* 2014) contains ca. 2.0 Ga Icartian basement and exposes a tectonic collage of units recording a complex, protracted igneous evolution from early ensimatic arc remnants at ca. 750–630 Ma to continental arc magmatism at ca. 580 Ma and a crustal melting event and abundant granites at ca. 540 Ma interpreted to reflect the final pulse of the Cadomian orogeny. Hence Cadomia as well as other Pan-African belts such as that in Cameroon (Fig. 9a) could have been the source of the lower Paleozoic sediments with an active margin or volcanic arc signature deposited on the Meguma terrane.

A similar pattern of Neoproterozoic-dominated detrital zircon populations and increasingly negative $\varepsilon_{Nd(t)}$ has also been documented in Avalonia in New Brunswick and Nova Scotia (Satkoski *et al.* 2010; Barr *et al.* 2012). However, Cambrian to early Ordovician sediments deposited in those areas contain a higher proportion of Mesoproterozoic zircon than the Goldenville and Halifax groups, and a less prominent Eburnean peak. Furthermore, Avalonia is generally viewed as an oceanic ribbon continent and unlikely to have provided the more than 13 km-thick (after lithification and metamorphism) pile of relatively uniform sediment that is represented by the exposed rocks of the Goldenville and Halifax groups. Hence Avalonia is a less likely contributor to the Goldenville and Halifax groups than Cadomia or other Pan-African belts combined with the landmass of the West African craton.

CONCLUSIONS

Combined with improved understanding of stratigraphy in the eastern part of the Meguma terrane, the additional isotopic data and detrital zircon compilation presented here provide increased support for the evolutionary pattern during deposition of the Goldenville and Halifax groups as described in the model of Waldron *et al.* (2009). In this model, deposition of this thick (>13 km) pile of sediment initiated in a rifted margin, with increasing sediment up-section from the West African craton. Hence, through the Cambrian and early Ordovician, sediments were derived from increasingly older and more age-diverse sources, while retaining a consistently strong component of Cryogenian and Ediacaran (Cadomian or "Pan-African") zircon ages. Petrographic characteristics and major- and trace-element chemical compositions are consistent with the detrital zircon and isotopic data by indicating the same depositional environment throughout deposition of the Goldenville and Halifax groups. However, the trace-element database is sparse considering the thickness of these sedimentary deposits, especially in the Halifax Group, and more data are needed to better constrain the timing of changes in sediment sources. More detrital zircon data are necessary, especially from the lower part of the Green Harbour Formation in the southeastern area of the Meguma terrane, and from the eastern area where the only detrital zircon spectrum is from the Halifax Group near the top of the stratigraphic section.

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APPENDIX

Table A1. Compilation of new and previously published Sm-Nd isotopic data* from the Goldenville and Halifax groups, Meguma terrane, Nova Scotia.

Map #	Sample #	Ch	GZ	Easting	Northing	Rock type	Group	Formation/ Member	Age (Ma)	Nd (ppm)	Sm (ppm)	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$	εNd (t)	εNd (0)	εNd (370)	TDM2	Data source
a13	H01-W09-136	y	20T	389034	4988767	metasiltstone	Halifax	Hells Gate Falls	470	34.30	6.39	0.1126	0.511869	-9.96	-15.0	-11.1	1927	This study
a12	A12-RT05-004	y	20T	286945	4943686	metasiltstone	Halifax	Bear River	485	51.27	9.28	0.1094	0.511879	-9.41	-14.8	-10.7	1854	Waldron *et al*. 2009
a11	O16-RT05-010	y	19T	727447	4864299	metasiltstone	Goldenville	Bloomfield	503	60.80	10.40	0.1031	0.511904	-8.31	-14.4	-9.9	1715	This study
a10	O16-RT05-011(LR042A)	y	19T	727368	4864751	metasandstone	Goldenville	Church Pt	505	20.81	3.85	0.1117	0.511991	-7.14	-12.6	-8.7	1729	Waldron *et al*. 2009
a09	O16-RT-05-013	y	19T	728656	4867810	metasandstone	Goldenville	Church Pt	510	21.45	3.89	0.1096	0.511981	-7.15	-12.9	-8.8	1709	Waldron *et al*. 2009
a08	O16-RT-05-014	y	19T	728321	4869531	metasandstone	Goldenville	Church Pt	520	20.35	3.83	0.1136	0.512015	-6.64	-12.2	-8.3	1726	Waldron *et al*. 2009
a07	O16-RT05-015	y	19T	727738	4870922	metasiltstone	Goldenville	High Head	530	28.40	5.68	0.1209	0.512132	-4.74	-9.9	-6.3	1670	This study
a06	LA-090	y	19T	727630	4870991	metasandstone	Goldenville	High Head	531	20.59	4.24	0.1244	0.512422	0.69	-4.3	-0.8	1243	Waldron *et al*. 2009
a05	O16-RT05-017	y	19T	727582	4873886	metasiltstone	Goldenville	Church Pt	535	21.10	4.34	0.1245	0.512138	-4.82	-9.8	-6.4	1727	This study
a04	B01-W13-002B	y	19T	726585	4878837	metasiltstone	Goldenville	Church Pt	538	37.10	7.50	0.1222	0.512263	-2.20	-7.4	-3.8	1477	This study
a03	B01-W13-001A	y	19T	726797	4878710	metamudstone	Goldenville	Church Pt	540	42.20	8.78	0.1258	0.512268	-2.33	-7.3	-3.9	1528	This study
a02	LA-089	y	19T	727834	4877396	metasandstone	Goldenville	Church Pt	543	17.52	3.45	0.1190	0.512407	0.89	-4.5	-0.9	1196	Waldron *et al*. 2009
a01	B01-RT05-18A	y	19T	727833	4877395	metasandstone	Goldenville	Church Pt	544	15.60	3.28	0.1275	0.512372	-0.38	-5.2	-2.0	1375	This study
b19	76-20		20T	410424	4928978	slate	Halifax	Cunard	494	65.35	12.46	0.1152	0.511864	-9.97	-15.1	-11.3	1985	Clarke and Halliday 1985
b18	A07-W06-086A	y	20T	365065	4913939	metasiltstone	Halifax	Cunard	495	10.82	2.34	0.1306	0.511937	-9.51	-13.7	-10.6	2218	Waldron *et al*. 2009
b17	A07-W06-086B	y	20T	365065	4913939	slate	Halifax	Cunard	495	41.08	7.27	0.1069	0.511877	-9.18	-14.9	-10.7	1813	Waldron *et al*. 2009
b16	76-18		20T	407867	4924763	slate	Halifax	Cunard	500	26.65	5.31	0.1205	0.511921	-9.13	-14.0	-10.4	2005	Clarke and Halliday 1985
b15	P15-RT05-027A	y	20T	350491	4870120	metasiltstone	Goldenville	Moshers Island	501	37.30	7.52	0.1218	0.512113	-5.45	-10.3	-6.8	1718	This study
b14	WXNS-17b	y	20T	320800	4853750	hornfels - metasiltstone	Goldenville	Government Pt	503	35.10	6.65	0.1146	0.511931	-8.53	-13.8	-10.0	1871	Currie *et al*. 1998
b13	WXNS-17a		20T	320800	4853750	hornfels - metasiltstone	Goldenville	Government Pt	504	11.73	2.45	0.1261	0.511891	-10.04	-14.6	-11.3	2184	Currie *et al*. 1998
b12	LA-084	y	20T	408396	4924408	metasandstone	Goldenville	Government Pt	505	22.08	4.16	0.1140	0.511902	-9.02	-14.4	-10.5	1904	Waldron *et al*. 2009
b11	76-13		20T	408640	4923762	metasandstone	Goldenville	Government Pt	506	23.95	4.48	0.1130	0.511881	-9.38	-14.8	-10.9	1917	Clarke and Halliday 1985
b10	P15-RT05-025A	y	20T	351142	4869124	metasandstone	Goldenville	Government Pt	508	20.09	3.80	0.1142	0.511983	-7.43	-12.8	-8.9	1785	Waldron *et al*. 2009
b09	76-22		20T	413439	4924618	metasandstone	Goldenville	Green Hbr	510	25.14	4.70	0.1130	0.511933	-8.31	-13.8	-9.9	1839	Clarke and Halliday 1985
b08	P15-RT05-023A	y	20T	352300	4868824	metasandstone	Goldenville	Green Hbr	511	17.70	3.47	0.1185	0.511975	-7.84	-13.0	-9.3	1878	This study
b07	P15-RT05-029	y	20T	353380	4868477	metasandstone	Goldenville	Green Hbr	515	23.20	4.36	0.1137	0.511995	-7.09	-12.6	-8.7	1758	This study
b06	A02-W05-153A		20T	375773	4894501	metasandstone	Goldenville	Lake Rossignol	520	24.50	4.64	0.1145	0.511980	-7.38	-12.9	-9.0	1795	This study
b05	A02-W13-003	y	20T	365707	4883099	metasiltstone	Goldenville	Green Hbr	530	37.80	7.46	0.1193	0.512028	-6.67	-11.9	-8.3	1809	This study
b04	A02-W05-027		20T	370201	4881098	metasandstone	Goldenville	Green Hbr	533	19.70	3.70	0.1136	0.512054	-5.74	-11.4	-7.5	1667	This study
b03	P13-W02-028	y	20T	263670	4849771	metasandstone	Goldenville	Moses Lk	535	17.50	3.85	0.1327	0.512439	0.49	-3.9	-0.9	1338	This study
b02	P13-WO2-085	y	20T	264760	4849158	metasandstone	Goldenville	Moses Lk	536	22.79	4.73	0.1255	0.512427	0.76	-4.2	-0.8	1250	Waldron *et al*. 2009
b01	P12-W02-002	y	20T	260746	4844529	metasandstone	Goldenville	Moses Lk	537	11.20	2.51	0.1350	0.512186	-4.59	-8.9	-6.0	1864	This study
c19	LR080B	y	20T	498149	4997829	metasandstone	Halifax	Glen Brook	480	16.18	3.14	0.1173	0.511927	-9.01	-13.9	-10.2	1930	Waldron *et al*. 2009
c18	LG064a	y	20T	516193	5007794	hornfels - metasiltstone	Halifax	Cunard	493	46.64	8.60	0.1113	0.511827	-10.46	-15.9	-11.8	1966	Clarke et al. 1993
c17	76-12	y	20T	447834	4943756	hornfels - slate	Halifax	Cunard	498	47.81	8.86	0.1120	0.511984	-7.38	-12.8	-8.8	1745	Clarke and Halliday 1985
c16	LG120-2	y	20T	526341	5013572	hornfels - metamudstone	Halifax	Cunard	500	32.45	5.96	0.1108	0.511930	-8.39	-13.8	-9.8	1805	Clarke et al. 1993
c15	LG094		20T	523777	5010568	xenolith in Porcupine Lk pluton	Goldenville	Taylors Hd	503	33.26	5.96	0.1082	0.511997	-6.82	-12.5	-8.4	1663	Clarke et al. 1993
c14	76-07	y	20T	451638	4961254	metasandstone	Goldenville	Taylors Hd	504	43.98	8.32	0.1143	0.511879	-9.51	-14.8	-11.0	1945	Clarke and Halliday 1985
c13	LG171-2	y	20T	517570	5006253	hornfels - metasiltstone	Goldenville	Taylors Hd	505	69.95	12.13	0.1047	0.511856	-9.33	-15.3	-11.0	1806	Clarke et al. 1993
c12	NS2/3	y	20T	431285	4970561	metasandstone xeno	Goldenville	Taylors Hd	507	43.53	8.06	0.1119	0.512031	-6.35	-11.9	-7.9	1673	Clarke *et al*. 1988
c11	NS2/4	y	20T	431285	4970561	metasandstone xeno	Goldenville	Taylors Hd	507	31.52	7.62	0.1461	0.512259	-4.12	-7.4	-5.1	2005	Clarke *et al*. 1988
c10	NS2/5b		20T	431285	4970561	metasandstone xeno	Goldenville	Taylors Hd	507	68.66	15.31	0.1348	0.512279	-3.00	-7.0	-4.1	1681	Clarke *et al*. 1988

APPENDIX

Table A1. Continued.

Map #	Sample #	Ch	GZ	Easting	Northing	Rock type	Group	Formation/ Member	Age (Ma)	Nd (ppm)	Sm (ppm)	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$	εNd (t)	εNd (0)	εNd (370)	TDM2	Data source
c09	SMB13-185	y	20T	511582	4979268	metasandstone	Goldenville	Taylors Hd	508	16.30	3.33	0.1230	0.511975	-8.16	-13.0	-9.5	1970	This study
c08	SMB13-186	y	20T	511127	4979788	metasiltstone	Goldenville	Taylors Hd	510	29.70	5.70	0.1159	0.511984	-7.50	-12.8	-9.0	1814	This study
c07	LG068	y	20T	523685	5006145	metasandstone	Goldenville	Taylors Hd	512	32.78	6.09	0.1121	0.511997	-6.98	-12.5	-8.6	1728	Clarke *et al*. 1993
c06	SMB13-183	y	20T	525299	4963752	metasandstone	Goldenville	Tangier	514	20.70	4.11	0.1202	0.512047	-6.51	-11.6	-8.0	1795	This study
c05	SMB13-184	y	20T	523336	4961278	metasandstone	Goldenville	Tangier	515	20.00	3.90	0.1177	0.512017	-6.92	-12.2	-8.4	1796	This study
c04	LR083A	y	20T	504308	4981611	metasandstone	Goldenville	Tangier	516	17.35	3.38	0.1179	0.512037	-6.54	-11.8	-8.1	1768	Waldron *et al*. 2009
c03	MR05-097-2	y	20T	504750	4980977	metasiltstone	Goldenville	Moose River	520	16.90	3.65	0.1306	0.512210	-3.96	-8.4	-5.3	1722	This study
c02	MR05-097-8	y	20T	504750	4980977	metasiltstone	Goldenville	Moose River	519	26.60	5.52	0.1253	0.512202	-3.77	-8.5	-5.2	1633	This study
c01	MR05-097-9	y	20T	504750	4980977	metasiltstone	Goldenville	Moose River	518	23.90	4.82	0.1219	0.512092	-5.71	-10.7	-7.2	1754	This study

*Analytical methods for this study are described in the manuscript text.
Abbreviations: Ch, whole-rock chemistry; y, yes (data available in Table S1); xeno, xenolith; Hd, Head; Lk, Lake; Hbr, Harbour