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Article abstract

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Whole-rock Sm-Nd isotopic data for both mafic and felsic compositions lie within previously delineated tightly constrained envelopes that define, respectively, the evolution of the Avalonian and sub-continental lithospheric mantle (SCLM), and crustal sources. These data imply that (i) the crust remained coupled to SCLM from the rifting of Avalonia from Gondwana to its accretion to Baltica in the Silurian and to Laurentia in the Early Devonian, and (ii) the Antigonish Highlands were located far from the subduction zone(s) that closed the Iapetus Ocean as it migrated northward, and so were only mildly affected by the resulting collisions.

Ordovician magmatism in the Antigonish Highlands, Nova Scotia, Canada: a tectonic model†

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ABSTRACT

The Antigonish Highlands form part of Avalonia in mainland Nova Scotia and are predominantly underlain by ca. 620–600 Ma low grade Neoproterozoic arc-related volcanic and sedimentary rocks and coeval plutons. The highlands also preserve a record of magmatism that spans much of the Ordovician (ca. 495–455 Ma), during which time Avalonia drifted from the northern Gondwanan margin and migrated as a microcontinent ca. 2000 km northward before becoming involved in collisions with Baltica and Laurentia in the Silurian to Devonian. The longevity of Ordovician magmatism (ca. 50 Ma) is consistent with a subduction-related environment, a setting that is compatible with most paleogeographic reconstructions. However, the continental tholeiitic-alkalic within-plate affinity of the mafic rocks and the A-type signature of the felsic rocks is more typical of a back-arc setting, rather than that of a typical arc. Furthermore, the A-type felsic rocks were derived from a hotter, drier lower crust than is typical for felsic arc magmas. Whole-rock Sm-Nd isotopic data for both mafic and felsic compositions lie within previously delineated tightly constrained envelopes that define, respectively, the evolution of the Avalonian and sub-continental lithospheric mantle (SCLM), and crustal sources. These data imply that (i) the crust remained coupled to SCLM from the rifting of Avalonia from Gondwana to its accretion to Baltica in the Silurian and to Laurentia in the Early Devonian, and (ii) the Antigonish Highlands were located far from the subduction zone(s) that closed the Iapetus Ocean as it migrated northward, and so were only mildly affected by the resulting collisions.

RÉSUMÉ

Les hautes terres d'Antigonish font partie d'Avalonia dans la section continentale de la Nouvelle-Écosse et elles reposent principalement sur des roches volcaniques et sédimentaires d'arc du Néoprotérozoïque, à faible teneur, d'environ 620 à 600 MA ainsi que sur des plutons du même âge. Les hautes terres préservent par ailleurs des traces du magmatisme qui a duré la majeure partie de l'Ordovicien (environ 495 à 455 Ma), période pendant laquelle Avalonia s'est détaché de la marge septentrionale de Gondwana pour migrer sous les traits d'un microcontinent sur environ 2 000 km vers le nord avant d'entrer en collision avec Baltica et Laurentia au cours du Silurien jusqu'au Dévonien. La longévité du magmatisme de l'Ordovicien (environ 50 Ma) correspond à un environnement de subduction, un milieu compatible avec la majorité des reconstitutions paléogéographiques. L'affinité intraplaque tholéiitique-alcaline continentale des roches mafiques et de la signature de type A des roches felsiques est toutefois plus caractéristique d'un milieu d'arrière-arc que d'un arc typique. Les roches felsiques de type A proviennent en outre d'une croûte plus basse et plus sèche que celle caractéristique des magmas d'arc felsiques.

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Les données isotopiques du Sm-Nd sur roche totale des compositions mafiques et felsiques se situent à l'intérieur des enveloppes strictement restreintes précédemment délimitées qui définissent, respectivement, l'évolution du manteau avalonien et lithosphérique subcontinental (MLS), ainsi que des sources crustales. Ces données laissent supposer que (i) la croûte est demeurée juxtaposée au MLS depuis le détachement d'Avalonia de Gondwana à son accrétion à Baltica au cours du Silurien, puis à Laurentia au cours du Dévonien précoce, et que (ii) les hautes terres d'Antigonish étaient éloignées de la ou des zones de subduction qui ont refermé l'océan Iapetus durant la migration vers le nord, de sorte qu'elles ont été peu affectées par les collisions consécutives.

[Traduit par la redaction]

INTRODUCTION

Deducing the evolution of Avalonia has been one of the most persistent themes in the career of Dr. Sandra Barr. In mainland Nova Scotia, it has long been established that Avalonia is exposed in the Cobequid Highlands and in the Antigonish Highlands (Fig. 1; Williams 1979; Keppie 1985; Pe-Piper and Piper 1989; Murphy *et al.* 1990). In the easternmost mainland, adjacent to Canso Causeway, research by Dr. Barr, in collaboration with Dr. Chris White (White *et al.* 2001, 2003), defined the Cape Porcupine Complex (Fig. 1) and showed that it was characterized by variably mylonitic metasedimentary, metavolcanic, and compositionally diverse plutonic rock units, separated from one another by major faults. The plutonic units include a relatively small body of leucodiorite, and a more voluminous suite of plutons with alkalic compositions (e.g. alkali-feldspar granite, syenogranite, alkali-feldspar syenite; quartz alkali-feldspar leucosyenite). Preliminary geochemical and geochronological data reported in White *et al.* (2003) implied that the leucodiorite was of arc affinity and similar in age and composition to arc-related plutons in the Antigonish Highlands. However, preliminary age data for the more alkalic compositions suggested an early Ordovician age, for which there were no obvious correlatives. At that time, few igneous rocks in the Antigonish Highlands had been dated by precise geochronological techniques, and undated plutonic units were mapped as either late Neoproterozoic or Devonian-Carboniferous, in part based on unpublished Rb-Sr isotopic data (Murphy *et al.* 1991).

Preliminary field investigations in the southern Antigonish Highlands (White and Archibald 2011; White *et al.* 2011) revealed the presence of undated, but lithologically similar rocks to the alkalic suite at Cape Porcupine, leading to two MSc theses (Escarraga 2010; Archibald 2012), based at Acadia University and co-supervised by S. Barr and B. Murphy. Collectively, these theses, and the publications based on them (Escarraga *et al.* 2012; Archibald *et al.* 2013), established an Ordovician age for the newly defined West Barneys River Plutonic Suite, described their field relationships and petrography, and provided geochemical data from which their tectonic setting could be interpreted. More specifically, these studies showed the West Barneys River Plutonic Suite to be geochemically bimodal, consisting of gabbro, as well as a felsic suite including alkali feldspar syenite-monzonite, alkali-feldspar syenite, and quartz alkali feldspar leucosyenite. The gabbro is transitional from tholeiitic to alkalic in composition and is characteristic of continental within-plate tectonic settings. The felsic suite has A-type within-plate geochemical characteristics. U–Pb (zircon, TIMS and LA-ICP-MS) geochronological data indicated that the emplacement of the West Barneys River Plutonic Suite occurred between ca. 495 Ma and 460 Ma (Archibald *et al.* 2013; LeBlanc 2023). The Cape Porcupine data were published by Barr *et al.* (2012) and confirmed the Neoproterozoic age (610 ± 3 Ma; U–Pb, zircon, TIMS) and volcanic arc geochemistry of the leucogranite. The alkali-feldspar granite, on the other hand, yielded an age of 478 ± 3 Ma (U–Pb, zircon, TIMS), and the alkalic suite in general showed A-type geochemical characteristics. In addition, a sample of alkali-feldspar leucosyenite yielded an age of 473 ± 9 Ma (U–Pb, zircon, LA-ICP-MS; Archibald *et al.* 2013). These data confirmed the affinity of the Cape Porcupine Complex with the Antigonish Highlands, as suspected by Barr *et al.* (2012) a decade earlier. Thanks to their initiative, it is now apparent that the Antigonish Highlands preserves a record of magmatism that spans the Ordovician (e.g., Murphy *et al.* 2018). The purpose of this paper is to evaluate the regional tectonic setting of this magmatism in the context of paleogeographic reconstructions (Fig. 2), which imply that Avalonia migrated more than 2000 km away from the Gondwanan margin during the Ordovician opening of the Rheic Ocean.

GEOLOGY OF THE ANTIGONISH HIGHLANDS OVERVIEW

The Antigonish Highlands (Fig. 1) are bounded to the north by the Hollow Fault and to the south by the Chedabucto Fault. They are predominantly underlain by ca. 620–600 Ma low grade arc-related volcanic and sedimentary rocks of the Georgeville Group and coeval plutons (Murphy *et al.* 1990, 1991; White *et al.* 2012;

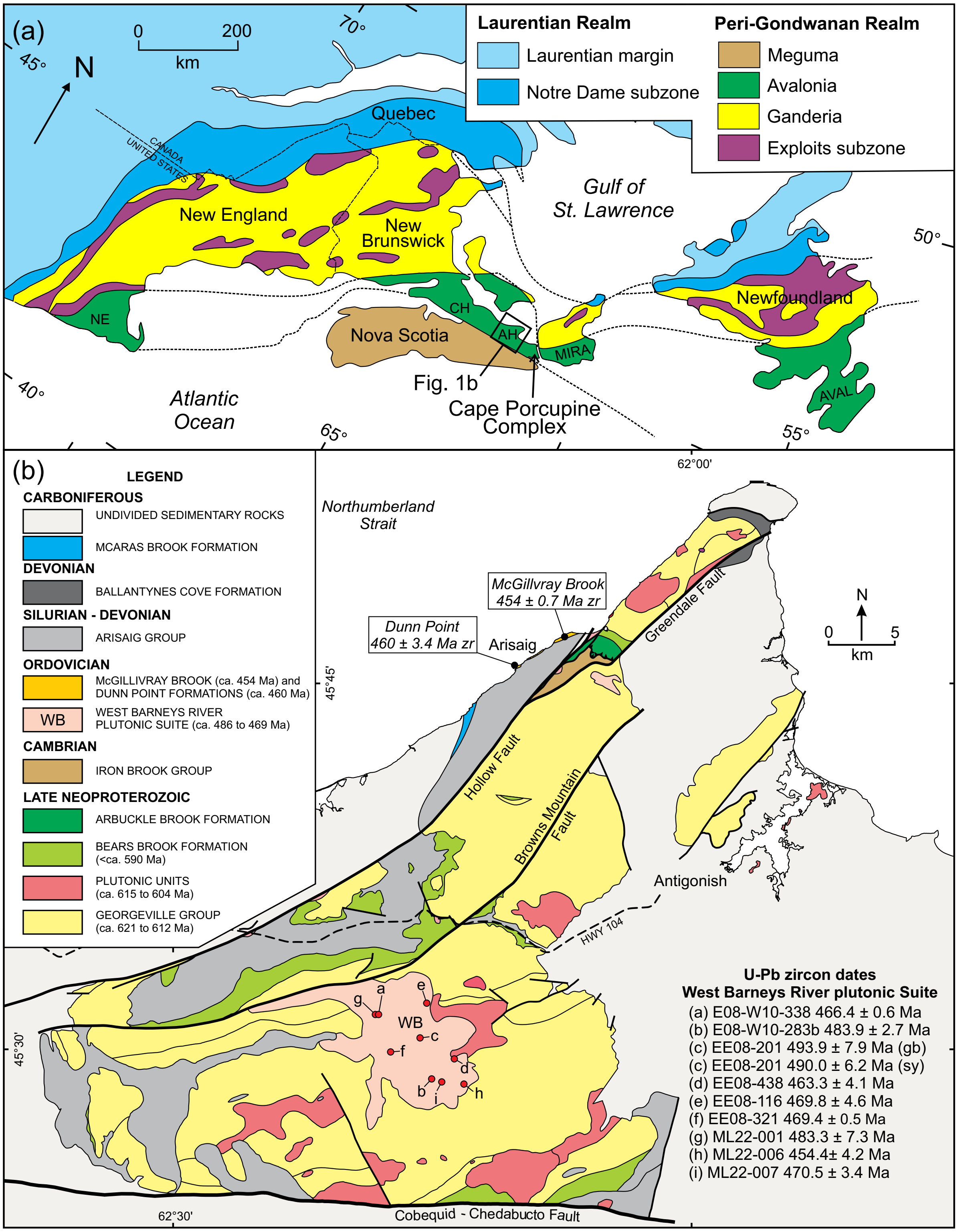

Figure 1. (a) Simplified tectonic map of the Appalachian orogen (modified after Hibbard *et al.* 2006, 2007). (b) Simplified geological map of the Antigonish Highlands (White *et al.* 2011; White 2017; White *et al.* 2021) showing the location of Ordovician plutons and volcanic units. Age data are from Hamilton and Murphy (2004), Escarraga *et al.* (2012); Murphy *et al.* (2012), Archibald *et al.* (2013), and Leblanc (2023). Abbreviations: AH, Antigonish Highlands; CH, Cobequid Highlands; MIRA, Mira terrane; AVAL, Newfoundland Avalon; NE, New England; gb, gabbro; sy, syenite; zr, zircon.

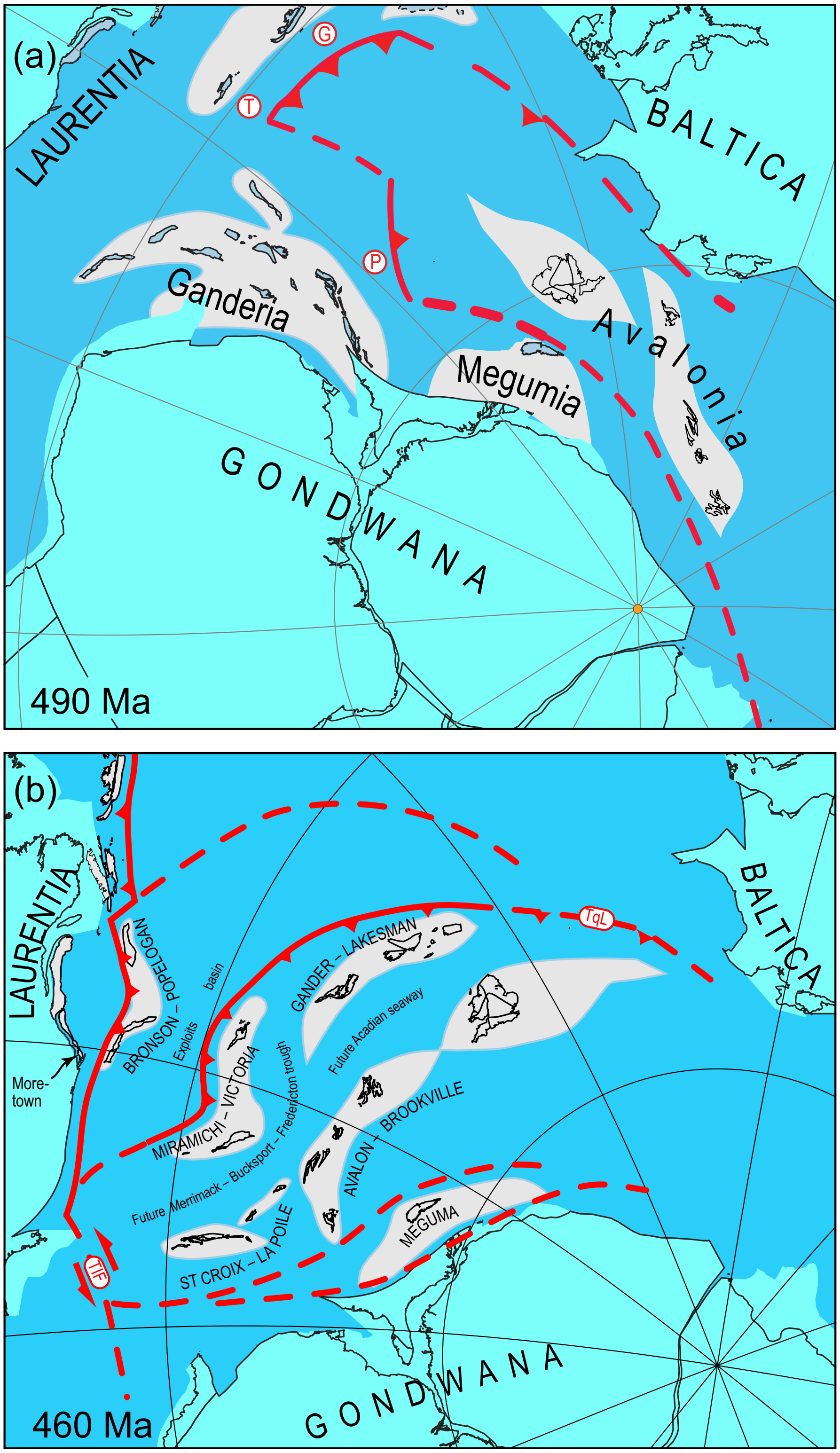

Figure 2. Paleogeographic reconstructions modified from Waldron *et al.* (2014, 2022) and references therein. (a) Furongian (490 Ma) reconstruction showing possible source domains for Iapetan terranes and subduction initiation. Orogenic episodes (red circles): G = Grampian; T = Taconian, P = Penobscottian/Monian. (b) Middle Ordovician (460 Ma). Small uppercase names are terrane assemblages; lowercase names are oceanic tracts. TqL = Tornquist line; TIF = Trans-Iapetus transform fault (Wu *et al.* 2022).

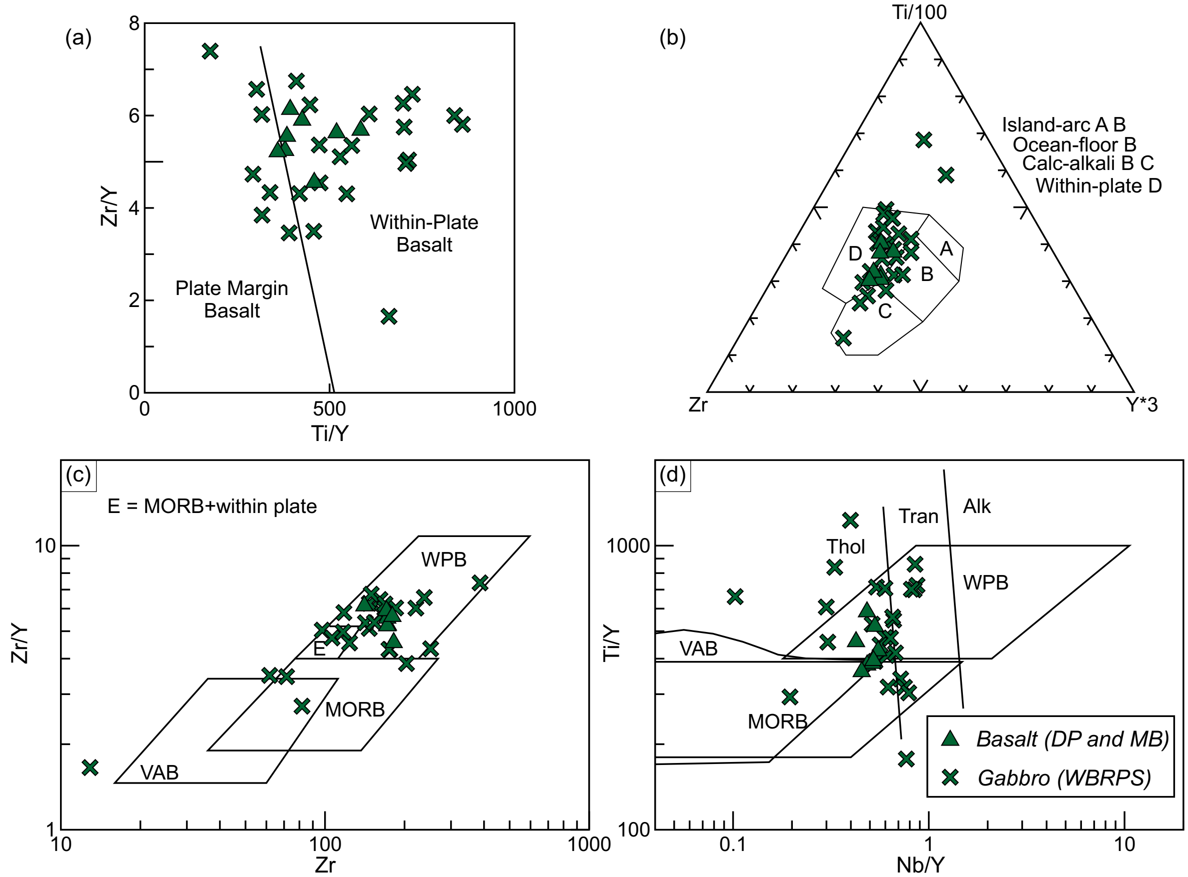

Figure 3. Geochemistry of Ordovician mafic rocks in the Antigonish Highlands: (a) Ti/Y against Zr/Y discrimination diagram (after Pearce and Gale 1977); (b) Ti–Y–Zr discrimination diagram (after Pearce and Cann 1973; Pearce 1996); (c) Zr/Y vs Zr discrimination diagram (after Pearce and Norry 1979); and (d) Ti/Y against Nb/Y discrimination diagram (after Pearce 1982, 1996). Data are from Escarraga *et al.* (2012), Murphy *et al.* (2012), and Archibald *et al.* (2013). Abbreviations: MORB, mid-ocean ridge basalt; WPB, within-plate basalt; VAB, volcanic arc basalt; thol, tholeiitic; tran, transitional tholeiitic to alkaline; alk, alkaline; DP, Dunn Point; MB, McGillvray Brook; WBRPS, West Barneys River plutonic suite.

White 2017; White *et al.* 2021; Archibald *et al.* 2024). Collectively, these rocks are local representatives of the ca. 640–570 Ma arc-related sequences that typify Neoproterozoic Avalonia. These rocks were deformed soon after deposition (Murphy *et al.* 1997) and were intruded post-tectonically by the ca. 580 Ma Georgeville Granite, which shares many geochemical and mineralogical features with A-type, within-plate granites (Murphy *et al.* 1998).

In the northern Antigonish Highlands, these rocks are uncon-formably overlain by two late Ediacaran to early Ordovician successions that are facies equivalents. One succession includes the predominantly volcanic (bimodal, within-plate) Arbuckle Brook Formation (Murphy *et al.* 1985), whereas the other comprises the predominantly sedimentary Iron Brook Group. The limited occurrence of these successions and others within Nova Scotia, and their fault-bounded nature (Fig. 1b), together with the intra-continental geochemistry of the bimodal volcanic rocks, is interpreted to re-flect deposition in a local pull-apart basin tectonic environment (Murphy *et al.* 2019). The Iron Brook Group contains pink limestones with typically Avalon-ian early Cambrian fauna (Landing *et al.* 1980; Landing and Murphy 1991). The upper part of the Iron Brook Group contains Early Ordovician ironstone beds (Ferrona Formation) that have been correlated with the Wabana Group in the Avalon terrane of Newfoundland (Dunn 2017; Todd *et al.* 2019; Matheson *et al.* 2022). According to Matheson *et al.* (2022), the Ordovician ironstones were deposited along the continental margin of the Rheic Ocean and required the involvement of ocean ridge hydrothermal waters that upwelled along the edge of the continental shelf to the sites of iron-stone deposition.

In the northern Antigonish Highlands, the two succes-

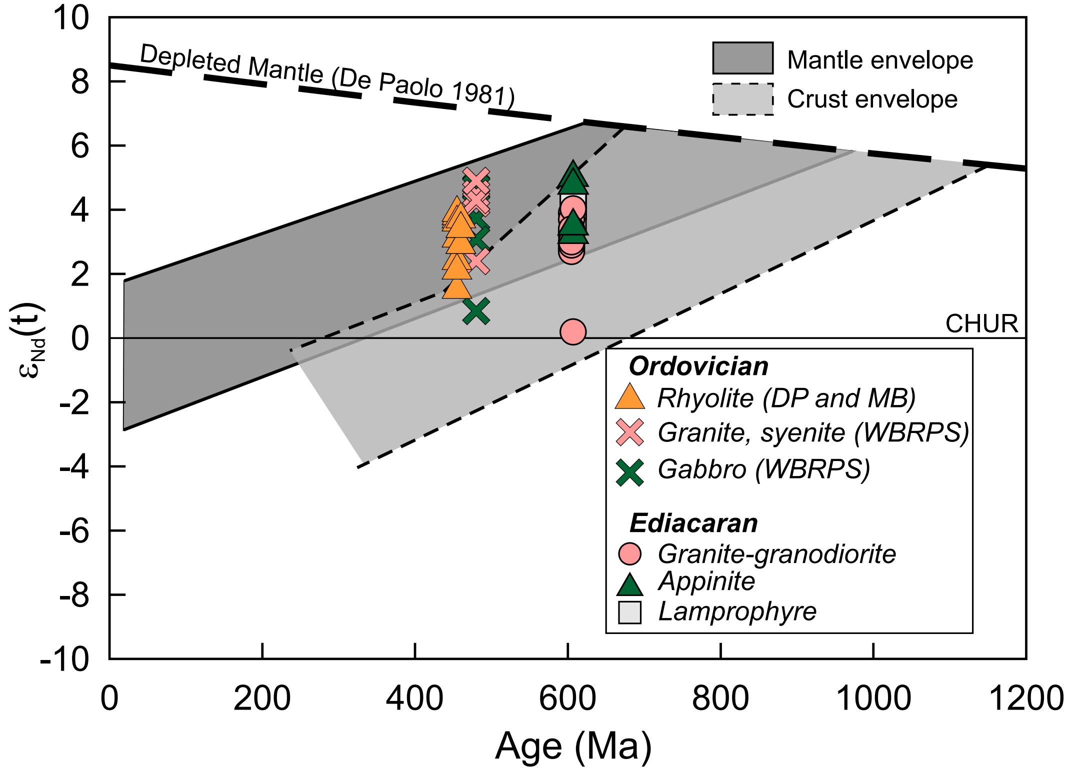

Figure 4. Plot of ε_{Nd}(t) against age for Ordovician rocks in the Antigonish Highlands. The field for the Avalonian crust envelope is from Murphy *et al.* (1996a) and the Avalonian mantle envelope is from Murphy and Dostal (2007) and Murphy *et al.* (2008). Data for Ediacaran plutons in the Antigonish Highlands are from White *et al.* (2021) and Archibald *et al.* (2024). The depleted-mantle evolution curve is from DePaolo (1981). Abbreviations: CHUR, Chondrite uniform reservoir; DP, Dunn Point; MB, McGillvray Brook; WBRPS, West Barneys River plutonic suite. Samples from the ca. 580 Ma Georgeville Granite are not plotted because metamict zircon has resulted in alteration of the primary Sm–Nd isotopic signature (Anderson *et al.* 2008).

sions were polydeformed prior to deposition of the ca. 460 Ma Dunn Point Formation (Keppie and Murphy 1988). The underlying Georgeville Group rocks are virtually unaffected by this deformation, indicating that the two groups of rocks were separated by a décollement surface close to, or at, the contact between them.

In the southern Antigonish Highlands, the bimodal West Barneys River Plutonic Suite intruded the Georgeville Group between ca. 495 and 460 Ma (Escarraga *et al.* 2012; Archibald *et al.* 2013). When considered in conjunction with plate reconstructions (Fig. 2), the earliest phases of this long-lived magmatic event could be interpreted as a local expression of the rifting of Avalonia from Gondwana. The geochemical and isotopic composition of the gabbroic rocks indicate that they are within-plate continental tholeiites, with some overlap into arc fields (Fig. 3). Sm–Nd isotopic data yield ε_{Nd}(t) values range from +0.84 to +4.66 (Archibald *et al.* 2013), which are consistent with derivation from Avalonian sub-continental lithospheric mantle (SCLM, Fig. 4). Felsic rocks are typical of within-plate ferroan A-type granitoid rocks (Fig. 5). ε_{Nd}(t) values range from +2.4 to +4.9 (Fig. 4), their similarity to the gabbroic rocks suggesting the two could be related by fractionation (Archibald *et al.* 2013). However, these ε_{Nd}(t) values are also within the range expected for magmas derived by anatexis of Avalonian crust (Murphy *et al.* 2018).

Middle Ordovician to Early Devonian rocks occur predominantly around the periphery of the Antigonish Highlands and unconformably overlie Cambrian to Early Ordovician and Neoproterozoic sequences (Boucot *et al.* 1974; Murphy *et al.* 1991). The lowest Middle Ordovician to Early Devonian strata are ca. 460 Ma (Hamilton and Murphy 2004) subaerial bimodal volcanic rocks and interbedded fluviatile red clastic sedimentary rocks (Dunn Point Formation), successively overlain by weathered and sheared trachyandesite (Seaspray Cove Formation, Jutras *et al.* 2020), basal lahar deposits, weathered rhyolite, felsic lapilli tuff, and the ca. 455 Ma felsic ignimbrite of the MacGillivray Brook Formation (Murphy *et al.* 2012).

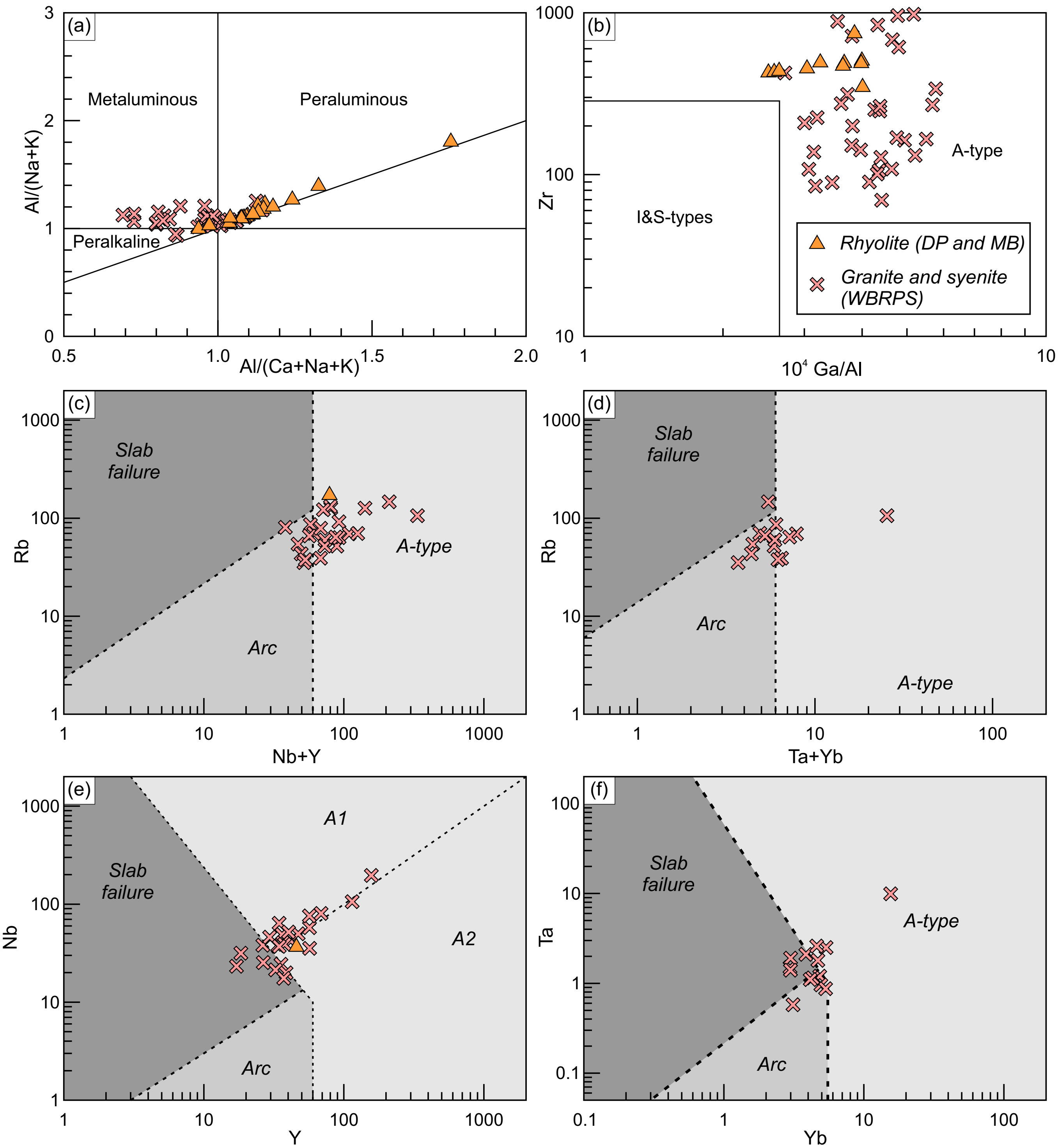

Figure 5. Geochemistry of Ordovician felsic rocks in the Antigonish Highlands: (a) Al/(Ca+Na+K) against Al/(Na+K) after Maniar and Piccoli (1989); (b) tectonic setting discrimination diagram from Whalen *et al.* (1987); (c–f) selected tectonic discrimination diagrams (Hildebrand *et al.* 2018; Whalen and Hildebrand 2019) plotting samples with SiO_2 concentrations between 55 and 70 wt. % and alumina saturation index (ASI) values <1.1. (c) Nb+Y against Rb; (d) Ta+Yb against Rb; (e) Y against Nb; and (f) Yb against Ta. Data from Escarraga *et al.* (2012), Murphy *et al.* (2012) and Archibald *et al.* (2013). Abbreviations: DP, Dunn Point; MB, McGillvray Brook; WBRPS, West Barneys River plutonic suite.

Paleomagnetic data from the Dunn Point Formation (Johnson and van der Voo 1990) indicate that Avalonia was at a paleolatitude of 41°S ± 8° at 460 Ma, i.e., about 1200 km north of the Gondwanan margin and ca. 1700–2000 km south of the Laurentian margin, with a latitudinal component of convergence between Avalonia and Laurentia from 460 to 440 Ma of about 5.5 cm/yr (van Staal *et al.* 2012).

Geochemical and Sm–Nd isotopic studies of the Dunn Point Formation indicate that the mafic rocks are Fe-Ti rich continental tholeiites and that the felsic rocks were derived by anatexis of typical Avalonian crust (Murphy *et al.* 2008). The McGillivray Brook Formation is dominated by felsic volcanic rocks with pronounced A-type compositions (Murphy *et al.* 2012). U–Pb zircon (TIMS) data yielded

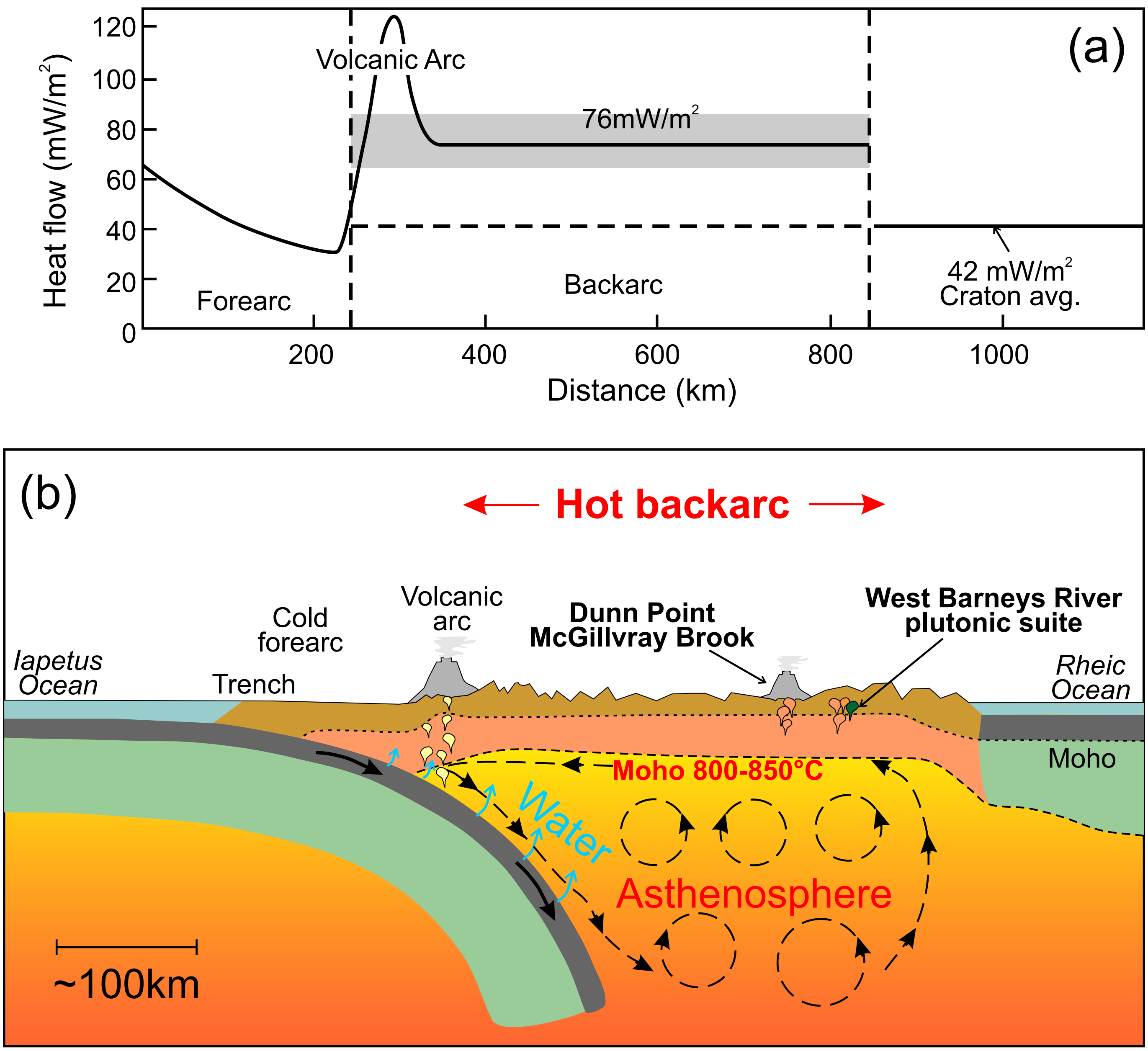

Figure 6. Schematic cross-sections of the modern Cascadia subduction zone, arc, and thin lithosphere hot back arc (modified after Hyndman *et al.* 2005). (a) Arc-back arc thermal regime, and (b) cross section of arc and back arc environments with suggested locations for Dunn Point and McGillvray Brook volcanism and West Barneys River plutonism. In hydrated environments (the volcanic arc), calc-alkaline arc magmas are produced. In contrast, melting in hot and dry back-arc environments produces A-type magmas. Arrows in the asthenospheric mantle wedge denote general sense of solid-state flow. See Currie *et al.* (2004), Hyndman *et al.* (2005), Hyndman and Canil (2021), and Hyndman and Wang (2025).

concordant ages of 460.0 ± 3.4 Ma for rhyolite in the Dunn Point Formation (Hamilton and Murphy 2004) and 454.5 ± 0.7 Ma for ignimbrite in the overlying McGillivray Brook Formation (Murphy *et al.* 2012). Given the paleogeographic context of Avalonia in the Middle to Late Ordovician as a microcontinent separating the Iapetus Ocean to the north from the Rheic Ocean to the south, this magmatism has been interpreted as reflecting a local intra-arc extensional environment, analogous to the modern setting of the Taupo Zone in New Zealand (Murphy *et al.* 2008).

These Ordovician volcanic-dominated successions are overlain by the early Silurian to Early Devonian Arisaig Group, consisting of 1900 m of fossiliferous, predominantly shallow marine siliciclastic rocks and minor bentonite beds (Boucot *et al.* 1974). The geochemistry of the Arisaig Group, combined with Sm–Nd and U–Pb (zircon) isotopic studies, indicate that the sedimentary rocks were *not* derived from the underlying, juvenile Avalonian basement but, instead, require derivation from more ancient continental crust (Murphy *et al.* 1996a, b, 2004). Paleocontinental reconstructions suggest two possibilities for the origin of this material. In some reconstructions, Avalonia was accreted to Baltica along the Tornquist line (e.g., Tornquist and Rehnström 2003 and references therein) during the ca. 15-million-year interval between the McGillivray Brook Formation and deposition of the basal strata of the Arisaig Group (Beechill Cove Formation) (Murphy *et al.* 1996a). Baltica would then provide a potential source for ancient detritus in the Arisaig Group. However, other reconstructions (Fig. 2) suggest that West Avalonia remained separate from Laurussia until the Devonian (e.g. Waldron *et al.* 2022), but acquired fragments of Ganderia during Monian/Penobscottian tectonism near the Gondwanan margin in the Furongian or Early Ordovician. These fragments are represented in the Brookville and Bras d'Or terranes of New Brunswick and Cape Breton Island respectively, and could have provided a source of ancient detritus during Silurian thermal subsidence following crustal extension (Waldron *et al.* 1996).

TECTONIC MODEL

The geochemical and isotopic data require that the respective mantle and crustal sources for the mafic and felsic magmas were both dry. In principle, such magmas can be generated in a variety of tectonic settings and so our tectonic model is guided by Ordovician paleogeographic reconstructions and by the longevity of magmatism (ca. 490–455 Ma).

Ordovician paleogeographic reconstructions imply that Avalonia separated from the Gondwanan margin in the early Ordovician and migrated ca. 2000 km northward as a microcontinent with the concomitant opening of the Rheic Ocean (Fig. 2). The longevity of magmatism, which continued long after Avalonia had separated from Gondwana and become a micro-continent, is consistent with a subduction-related setting, a conclusion compatible with plate reconstructions (e.g., Cocks and Torsvik 2002, 2021; Scotese 2023; Stampfli and Borel 2002; Domeier 2016; Wu *et al.* 2022; Waldron *et al.* 2022) and regional syntheses (e.g., van Staal *et al.* 1998, 2009, 2012) that imply opening of the Rheic Ocean by subduction zone rollback (Fig. 2).

However, the continental tholeiitic within-plate affinity of the mafic rocks implied by their geochemistry, and the persistent A-type chemistry of the felsic rocks, suggest the magmatism did not occur in a typical arc or back-arc basin setting. Indeed, the A-type chemistry implies derivation from melting of hotter, drier crust (Whalen *et al.* 1987; Collins *et al.* 2021) than that typical of arc or back-arc magmas, which inherit their geochemical traits (e.g., enrichment in large ion lithophile elements, depletion in high field strength elements) from a mantle source hydrated and metasomatized by subduction zone fluids (e.g., Pearce 1996; Tatsumi and Kogiso 2003).

Dry crust exists in the distal (hinterland) regions of continental back-arcs, i.e. in the region behind that where typical arc or back-arc basin magmas originate from a mantle source metasomatized by subduction zone fluids. Distal back-arc regions are typically ca. 200–600 km from the trench, where the crust is uniformly hot, dry and thin (e.g., Hyndman 2015, 2023) and where, under steady-state conditions, temperatures are ca. 850°C at the base of the crust and ca. 1350°C at the lithosphere-asthenosphere boundary. Indeed, Condie *et al.* (2023) point out that A-type compositions are common in Phanerozoic back-arc settings, including the distal back-arc regions of the iconic Lachlan fold belt of eastern Australia (Collins *et al.* 2020).

A compilation of whole-rock Sm–Nd isotopic data for Neoproterozoic–Devonian igneous rocks shows that all mafic and felsic compositions lie within tightly constrained envelopes that define, respectively, the evolution of the SCLM and crustal sources (Fig. 4; Murphy *et al.* 2008). These data imply that the crust and sub-continental lithospheric mantle beneath the Antigonish Highlands not only remained coupled during the rift-drift of Avalonia from Gondwana in the Ordovician, but also during its accretion to Baltica and Laurentia in the Silurian and early Devonian. These data are consistent with the proposed distal back-arc (rather than intra-arc; Murphy *et al.* 2008) setting as the Avalonian microcontinent migrated northward (Fig. 2). A distal back- arc location is also consistent with (i) the continental margin setting along the northern flank of the Rheic Ocean proposed for the deposition of the Early Ordovician Ferrona Formation ironstones (Matheson *et al.* 2022), and (ii) the lack of significant discordance between the Dunn Point and McGillivray Brook volcanic units, and the basal formation of the Silurian-early Devonian Arisaig Group (Beechill Cove

Group (Beechill Cove Formation). In this context, the collision between Baltica and the Gander–Lakesman terrane assemblage (Fig 2), which is constrained to the interval between the deposition of the MacGillivray Brook Formation and that of Beechill Cove Formation, may provide an explanation for the cessation of this protracted interval of magmatism.

According to Hyndman (2023) and Hyndman and Wang (2025), back-arc areas are anomalously hot, irrespective of whether they are under extension or compression (Fig. 6). As a result, their crust should be thin and elevated. The occurrence of Early Ordovician ironstones, coupled with the Early Silurian deposition of marine strata, suggest it is unlikely that the Antigonish Highlands were significantly topographically elevated, a scenario consistent with crustal extension caused by the subduction zone roll-back that is implicit in most Ordovician reconstructions (e.g., Stampfli and Borel 2002; Domeier 2016; Cocks and Torsvik 2021; Waldron *et al.* 2022; Scotese 2023).

But if Ordovician magmatism in the Antigonish Highlands was generated in a distal back arc environment, where is the arc? Regional syntheses (e.g., van Staal *et al.* 2009, 2021; van Staal and Barr 2012; Waldron *et al.* 2022) provide several possibilities. According to these syntheses, Ganderia and Avalonia, although separated by the Acadian seaway, may have resided on the same plate (Fig. 2). If so, the coeval calc-alkaline volcanics of the Ganderian Lake District–Leinster volcanic arc in the UK and Ireland, including the Borrowdale Volcanic Group and the ca. 480–450 Ma Bellewstown-Lambay belts, may represent the arc (Woodcock 2000; McConnell *et al.* 2002, 2021; Stillman 2008). Further south in Ganderia, Ordovician magmatism in Ireland (Avoca) and the Welsh borderlands has been interpreted to reflect back-arc basin magmatism (Leat and Thorpe 1986; McConnell *et al.* 1991, 2021; Woodman 2000). In this scenario, Antigonish Highlands Ordovician magmatism would reflect the distal back-arc region of a Ganderian arc.

An alternative possibility is suggested by the geochemistry of Devonian granitoid magmas that intruded Ganderia after it had accreted to Laurentia (Yousefi *et al*. 2023; Wang *et al.* 2024). The Avalon-like geochemistry of these granites has been interpreted to reflect underthrusting of the leading edge of Avalonia beneath the Ganderian margin of composite Laurentia in the Early Devonian or later (Wintsch *et al.* 2014), forming a source for the post-collisional Devonian granitoid magmas (Yousefi *et al.* 2023; Wang *et al*. 2024). If so, the Ordovician Avalonian arc was likely destroyed although the possibility that tectonic slivers may have been preserved in the collision zone cannot be discounted. Evidence of the arc's former existence may also be preserved in the detrital zircon records of strata deposited in the Acadian seaway, between Avalonia and Ganderia in the Silurian, or in younger strata recycled from those deposits.

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