Orogenic architecture diagrams to reconstruct paleogeography and plate tectonics: Newfoundland (Canada) as a case study

Abbreviated title: Orogenic architecture diagrams

Alice Maremmani[1*], Douwe J.J. van Hinsbergen[2], Eldert L. Advokaat[2], Alissa J. Kotowski[2], Carl Guilmette[3,4]

[1]*Instituto de Geociencias (IGEO-UCM), Consejo Superior de Investigaciones Científicas, Madrid 28040, Spain*

[2]*Department of Earth Sciences, Utrecht University, Princetonlaan 8A, 3584 CB Utrecht, Netherlands*

[3]*Département de Géologie et Génie Géologique, Université Laval, Québec, Canada*

[4]*Centre de Recherche sur la Géologie et L'ingénierie des Ressources Minérales (E4m), Québec, QC G1V 0A6, Canada*

ORCID ID: AM 0009-0005-9483-0746; DJJH 0000-0003-3410-0344; ELA 0000-0001-8239-0310; AJK 0000-0002-1257-4402; CG 0000-0001-7196-522X

*Corresponding author: Alice Maremmani, a.maremmani@csic.es

ABSTRACT

Reconstructing paleogeography from accretionary records is challenging due to the difficulty of integrating data sources transcending a range of fields and scales. Here, we present the 'orogenic architecture diagram' method to systematically compile geological data in temporal and spatial context at the scale of the 'building blocks' of orogens and to use their interpreted geological histories as a base for tectonic and paleogeographic reconstruction. We identify lower plate-derived Continental or Ocean Plate Stratigraphy, and upper plate-derived ophiolites and magmatic units. We apply this framework to the Newfoundland Appalachians, Canada, which record accretion of oceanic and Gondwana- and Laurentia-derived continental units to Laurentia during the Cambro-Ordovician closure of the Iapetus Ocean. Our diagrams allow for straightforward connection of modern geological records to opening and closure of marginal oceanic basins and illustrate that the Iapetus Ocean itself left little accretionary record. Our approach highlights the source of contrasting interpretations in Newfoundland reconstructions and may motivate targeted field campaigns – here and elsewhere within the orogen – to interrogate proposed models. Our application to Newfoundland also demonstrates that our protocol, based on modern-style plate tectonics and orogenesis, still applies to early Paleozoic orogens and may provide a tool to reconstruct the emergence of plate tectonics.

This manuscript has been accepted for publication in the *Journal of the Geological Society* and is published open access. Please cite the published version, available at https://doi.org/10.1144/jgs2026-039

The destructive nature of subduction makes reconstruction of past paleogeography and plate kinematics challenging, but such reconstructions form the basis of paleo-environmental, paleo-climatic, and geodynamic research. The only direct observations for reconstructing the motions of subducted plates – and oceans, continents, and arcs built upon them – come from offscraped upper crustal rocks that comprise accretionary orogens (Şengör 1990; Cawood *et al.* 2009; van Hinsbergen and Schouten 2021). Indirect observations on e.g., magmatism or basin development, may then provide additional evidence, although they do not allow to precisely locate the suture. Orogenic reconstructions are based on interpretations of thrust packages which record features of paleogeographic and plate tectonic significance, such as sedimentation, paleontology, magmatism, geochemistry, paleomagnetism, deformation and metamorphism. In isolation, these sources of information permit a large variety of paleogeographic and plate tectonic scenarios (Fig. 1). As a result, it is challenging to navigate and interrogate interpretations derived from specialized fields. This complicates reproducibility of paleogeographic interpretations. Therefore, it is crucial to reassess the original, uninterpreted data across a variety of fields and scales in light of evolving understanding of plate tectonic processes.

There is a large interpretative step between detailed field observations and plate tectonic or paleogeographic reconstructions. If we integrate different data types related to paleogeography and tectonics on a more local scale and systematically organize data and examine first-order interpretations, then we can identify less controversial building blocks that then add up to interpretations of orogenic architecture. Such analyses may restrict interpretation to the paleoenvironment recorded by individual structural units (e.g., syn-rift, foreland basin, ocean basin, arc etc.) or their tectonic history (e.g., shortening, metamorphism, exhumation). This strategy organizes data sources into a regional geological history of sedimentation, paleontology, igneous history, deformation and metamorphism. Such organization of data has been done in the past in different ways (e.g., Handy *et al.* 2010; van Staal and Barr 2012; van Hinsbergen *et al.* 2020; van Hinsbergen and Schouten 2021; Wakabayashi 2021) but, so far, no explicit methodology for this approach was proposed.

In this paper, we describe the construction of 'orogenic architecture diagrams', which summarize and interpret data from various fields into paleogeographic and tectonic building blocks. Each building block, which has been offscraped from a downgoing plate, and accreted to an overriding plate, has a specific architecture (i.e., tectonostratigraphy and internal features) and first-order geological history, which is typically more straightforward to interpret than at larger scales. We describe how to then zoom out and interpret the product of these building blocks – i.e., orogenic reconstruction.

As a case study, we selected the Caledonian-Appalachian belt, and specifically a section of the orogen located in Newfoundland (eastern Canada), which has been extensively described and dated (e.g., Williams 1979, 1995; van Staal *et al.* 1998; van Staal and Barr 2012; White and Waldron 2022). Newfoundland has a well-defined structure comprising accreted continental and oceanic rocks, ophiolites, and records of arc magmatism and sutures, and contains a wide variety of paleogeographic and plate tectonic elements. Current interpretations posit that the Newfoundland Appalachians record evidence for several subduction systems, with models proposing anywhere from ca. 3 to 6 stages of both short- and long-lived subduction (e.g., van Staal *et al.* 1998; van Staal and Barr 2012). We first explain the orogenic architecture diagram concept, and then present diagrams capturing a systematic review of the Newfoundland architecture. We then interpret paleogeography and plate tectonics from the diagrams (without influence of past research) and compare it with proposed models. Finally, we discuss the utility of the diagrams for building reproducible paleogeography and plate tectonic scenarios, and alternatively, as tools for interrogating past interpretations and identifying future research targets (e.g., regions with lower data quality or density, or with ambiguous interpretation).

OROGENIC ARCHITECTURE DIAGRAMS: THE APPROACH

Schematic visual representations of the building blocks of orogens have been used in many forms, and commonly summarize key observations that authors use as basis for their reconstructions. Those diagrams contain some combination of stratigraphy and lithology, metamorphism, magmatism, and the structural relationship between the building blocks, such as thrust vergence and timing of emplacement (e.g., Handy *et al.* (2010) for the Alps, van Staal and Barr (2012) for the Appalachians, van Hinsbergen *et al.* (2020) for the Mediterranean fold-thrust belts, Boschman *et al.* (2021) for Hokkaido, Japan, Advokaat and van Hinsbergen (2024) for the SE Asian orogen, and Wakabayashi (2021) for the Franciscan complex of California). The orogenic architecture concept is based on recognizing fault-bounded units in an orogen as distinct carriers of information on the paleogeography that existed on the tectonic plate they derive from, and on the motion of the tectonic plate. Therefore, distinguishing upper and lower plate units is crucial, as this allows to separately reconstruct the pre-orogenic paleogeography of the plates and the transfer of units from downgoing to overriding plates during accretion. We subdivide the structural units in orogens in upper plate-derived units, such as ophiolites, and lower plate-derived units that represent the offscraped top parts of now-subducted lithosphere. We refer to the latter units as 'nappes', even though they may contain thick, basement-involved crustal sequences that are much thicker than the thin-skinned thrust slices that are typically defined as 'nappe'. It is important to note that this concept is developed under the paradigm of plate tectonics and the Wilson cycle (Wilson 1966), which are thus taken as the base assumptions. Herein we define the type-stratigraphy, -geochemistry and -metamorphic conditions characterising lower and upper plate units. The fault-bounded units form the 'building blocks' for the orogenic architecture diagrams (Fig. 2).

Upper Plate Units

Upper plates can consist of oceanic or continental lithosphere. Continental upper plates typically contain remnants of earlier accretionary orogens, as well as younger magmatic rocks and sedimentary basins. Continental upper plates have a large preservation potential in the geological record. Particularly, records of final ocean closure and continent-continent collision are typically well-preserved.

On the other hand, oceanic upper plates are more likely to eventually subduct and disappear in another, younger subduction zone. However, if accretionary orogens formed below oceanic upper plates – i.e., as a thickening accretionary wedge – their forearc may become uplifted and escape subduction. Such slices of oceanic forearcs may then be preserved as ophiolites, which represent the most complete remains of oceanic upper plates. Given their significance for reconstructing past intra-oceanic subduction, we identify upper plate ophiolites as distinct units in orogenic architecture diagrams (Fig. 2).

Ophiolites. Ophiolites offer several key diagnostic features to reconstruct oceanic upper plates and subduction history. Ophiolites in their most complete sequence comprise, from bottom to top, peridotites, gabbro, a sheeted dyke complex and pillow basalts, overlain by chert and/or pelagic sediments (i.e., the 'Penrose' sequence; Anonymous 1972). Deep-water sediments may be overlain by forearc deposits derived from an intra-oceanic arc or a nearby continental margin (Fig. 2). U-Pb igneous zircon crystallization ages and cross-cutting relationships constrain the ages of upper plate spreading to produce the ophiolite sequence. Many ophiolites exhibit a SSZ (supra-subduction zone) geochemical signature, indicating that they formed above a subduction zone (Pearce *et al.* 1984), typically during (e.g., Stern and Bloomer 1992) or shortly after subduction initiation (Guilmette *et al.* 2018, 2023). Subduction initiation-related ophiolites are commonly floored by a metamorphic sole, derived from the subducting plate (see below). Where ophiolites have MORB geochemistry, they may represent ocean floor that (long) predates subduction initiation (e.g., the Jurassic Masirah MORB ophiolite of east Oman that was uplifted above a late Cretaceous subduction zone; Peters and Mercolli 1998). In the orogenic architecture diagram, the ophiolite's age, geochemical composition, and sedimentary cover may be documented, as well as intervals where paleomagnetic data exist. If ophiolites are disrupted and preservation is poor, it may become challenging to distinguish between upper plate ophiolite or lower plate-derived oceanic units (OPS, see below). In this case, upper plate ophiolites may be recognized geochemically (Pearce *et al.* 1984). Furthermore, upper plate ophiolites are typically disrupted by erosion or extension and their mantle sections are often best preserved, whereas lower plate-derived units are offscraped from downgoing plates and typically only consist of upper crustal units. This, combined with the geochemistry, may be used as further guidance.

Arcs, basins, and upper plate deformation. Magmatic arcs typically form ~100-250 km inboard of a trench, above a subducting plate, whereby the arc-trench distance is a measure for slab dip (e.g., Stern 2002). Arcs may not be preserved in the geological record of ocean-ocean subduction, because the width of oceanic (i.e., ophiolite) belts thrust onto continental margins rarely exceeds 150 km (e.g., van Hinsbergen *et al.* 2015). Where preserved, however, we treat them as separate units intruding ocean floor or continental crust, or accreted units (Fig. 2).

Upper plates may record shortening, extension, and/or strike-slip deformation, which needs to be restored to correctly identify the geometry and location of accretion of the oceanic and continental lower plate units. Details of restoring upper plate deformation is beyond the scope of this paper, but systematic reconstruction protocols were developed and applied that restored upper/intraplate deformation in order of decreasing certainty from extensional (whereby a complete geological record is preserved at the end of the tectonic event), through transcurrent, to contractional deformation (where only a minimum record is preserved, e.g., van Hinsbergen and Schmid 2012; Boschman *et al.* 2014; van Hinsbergen *et al*. 2014, 2020).

Lower Plate Units

During subduction, the upper units of the downgoing plate may accrete to the upper plate. We analyse nappe records to reconstruct the pre-accretionary history of the lower, subducting plate. Accreted units can be either oceanic (Ocean Plate Stratigraphy (OPS); Isozaki *et al.* 1990) or continental in nature (Continental Plate Stratigraphy (CPS); van Hinsbergen and Schouten 2021). OPS are quite common in orogenic systems, although the default behaviour of oceanic lithosphere is wholesale subduction without accretion: the known records of OPS, such as in the accretionary orogen of Japan, represent only a small fraction of the area of subducted oceanic lithosphere (Isozaki *et al.* 1990). On the other hand, the paradigm that historically underlies paleogeographic reconstruction is that continental lithosphere that arrives in subduction zones does not subduct without leaving a geological record that is representative for the area of subducted lithosphere (van Hinsbergen and Schouten 2021). Continental margins may be dragged into subduction zones, as shown by (ultra) high-pressure conditions recorded in continental protoliths (Brown 2007), but the area of continental lithosphere that is restored from accreted fold-thrust belts of passive margin sediments, such as in the eastern Mediterranean region (van Hinsbergen *et al.* 2020) is representative for the original continental area. There are currently no documented examples of continental fragments that must have existed according to e.g. passive margin reconstructions, of which no geological record can be found (see discussion in Advokaat and van Hinsbergen 2024).

Ocean Plate Stratigraphy (OPS). Several authors inferred that oceanic plates record characteristic sequences of igneous rock types from ridge spreading to entering a trench (e.g., Cawood 1982; Isozaki *et al.* 1990). This concept was then termed 'Ocean Plate Stratigraphy' by Isozaki *et al.* (1990). A complete OPS (Fig. 2) consists of remains of ocean floor magmatic rocks (typically pillow basalts, but in some cases also lower crustal rocks), overlain by deep-marine radiolarian chert, followed by distal hemipelagic sediments which may then be overlain by increasingly proximal trench-fill deposits ('flysch') deposited as the sequence approached the trench where it accreted. Biostratigraphic ages of the pelagic sediments (and, in rare cases, U-Pb zircon ages of gabbros and plagiogranites in the crustal sequences) constrain the maximum age of formation of the ocean floor, and the biostratigraphic or detrital zircon ages of foreland basin deposits constrain timing of arrival at the trench and the maximum age of accretion. The age gap constrains the age of the oceanic lithosphere that subducted when the OPS accreted (Isozaki *et al.* 1990). Geochemistry reveals if the oceanic crust formed at a mid-ocean ridge (MORB), hotspot or seamounts, or an intra-oceanic arc. If geochemistry indicates an ocean island basalt (OIB) or island arc tholeiite (IAT), the age of these magmas represents only a minimum age of the ocean floor as they intrude into or are emplaced onto an already existing oceanic crust. Such seamounts may be overlain by shallower-marine sedimentary facies such as carbonate reefs. If present, the tectonostratigraphic level where paleomagnetic data constrains paleolatitude can be added (e.g., van de Lagemaat *et al.* 2024). In our case study, we have not included a review of available paleomagnetic constraints.

The completeness of an accreted stratigraphy depends on the depth of a decollement, which for oceanic plates typically occurs around the sediment-crust interface (van Hinsbergen and Schouten 2021). Such decollement depth may vary along strike, so that basalts or radiolarian cherts can be found as discontinuous lenses. OPS may develop coherent nappes, or more chaotic assemblages in broken formations and mélanges (e.g., Wakita 2015; van Hinsbergen and Schouten 2021 and references therein). However, even in the latter case, composite stratigraphies tend to still retain first-order coherence, and may still be useful to restore subducting plate history (e.g., Wakabayashi 2021; Kotowski *et al.* 2022). Where rocks are frontally accreted, they will not metamorphose as long as they are unaffected by upper plate thickening. If they accrete at depth below the orogen, they may become metamorphosed, typically up to high-pressure/low-temperature (HP/LT) conditions, and may provide minimum estimates for the age of accretion. Radiogenic isotopes analyses of the metamorphic assemblages may quantify the minimum timing of accretion (e.g., Kotowski *et al.* 2022).

Metamorphic soles are a special type of OPS and are characterized by thin, high-grade metamorphic rocks derived from subducted oceanic crust that accreted to the mantle base of supra-subduction zone ophiolites during subduction initiation (e.g., Jamieson 1981; Hacker and Gnos 1997;

Wakabayashi and Dilek 2000). Soles are diagnostic features that confirm ophiolites are upper plates. Soles are the oldest, and highest structural units of the accretionary orogen that formed below the ophiolite, and their metamorphic ages indicate minimum ages of subduction initiation (e.g., Guilmette *et al.* 2018, 2023). Lu-Hf garnet ages of metamorphic soles record initial burial, whereas metamorphic U-Pb zircon ages of the sole and magmatic U-Pb zircon ages of the overlying ophiolite record upper plate extension and may post-date the garnet ages (Guilmette *et al.* 2018). For the orogenic architecture diagrams, we define metamorphic soles as separate accreted nappes consisting of OPS, and indicate their metamorphic grade and age (Fig. 2). Further details may include protolith age or composition, if known.

Continental Plate Stratigraphy (CPS). Continental-affinity accreted units – with a Continental Plate Stratigraphy (CPS, van Hinsbergen and Schouten 2021) – are typically organized in fault-bounded, coherent nappes (Fig. 2). In its most complete form, a CPS contains a continental basement of an earlier orogenic event, which is typically heterogeneous and is made up of (metamorphosed) OPS, CPS, or magmatic units. The basement is commonly overlain by clastic syn-rift sedimentary rocks from continental break-up, often associated with mafic or bimodal magmatism. Syn-rift sequences are then overlain by fining-upward post-rift passive margin sediments that are usually pelagic or hemipelagic; the base of this sequence represents the transition from rifting to drifting. Finally, the passive margin sediments are overlain by coarsening upward active margin foreland basin deposits (i.e., flysch), which indicate proximity to and subsequent arrival at the trench and provide a maximum age of accretion. This simple stratigraphy may be more complex if margins underwent multiple phases of rifting, or due to climate or sea level changes, influencing specific alternations of rock types and paleo-stratigraphy. Such complexities aid the interpretation of pre-orogenic paleogeography and may be incorporated into orogenic architecture diagrams. Similar to OPS, nappes buried below the upper plate may record metamorphism (high-pressure/low-temperature for thinned continental margins, or medium-pressure/high-temperature for thicker margins, cf. van Hinsbergen *et al.* 2024). This metamorphism gives a minimum age for accretion. Ages of exhumation constrained from cooling histories help reconstruct upper plate deformation. Like OPS, accretion of CPS usually occurs after subduction of an oceanic basin, and the amount of accreted material depends on the depth of decollement from the subducted lithosphere. Such detachment horizon may localize at the brittle-ductile transition, or at the interface between the sediment column and underlying crystalline basement, with the deeper parts having a smaller chance of accretion (van Hinsbergen and Schouten 2021, and references therein).

REVIEW OF THE GEOLOGY OF NEWFOUNDLAND

The geologic architecture of the Appalachians comprises tectonostratigraphic slices that are interpreted as the ancient margins of Laurentia (the Humber zone of Williams 1979), of sedimentary and igneous relicts of oceanic basins (the Dunnage zone of Williams 1979, interpreted as the relicts of the Iapetus Ocean or other oceanic basins), and continental stratigraphy and igneous rocks that do not resemble Laurentia, interpreted as exotic microcontinents (e.g., Ganderia, Avalonia) that accreted to Laurentia upon closure of the Iapetus Ocean (Fig. 3). All units are interpreted to have amalgamated between the Ordovician and the early Devonian (e.g., van Staal and Barr 2012). The orogen is intruded by Silurian to Devonian (younging progressively NW to SE) granites that may have resulted from melting of the orogenic crust due to thickening, mantle delamination or slab break-off (Whalen *et al.* 1996, 2006; Wang *et al.* 2024). In addition, late Paleozoic strike-slip faults that run parallel to the orogen have laterally displaced accreted units derived from the Iapetus oceanic domain relative to the Laurentian continental margin units, e.g., along the Cabot Fault. Displacement estimates are variable, with a maximum of ~250 km for the Cabot Fault deriving from extrapolation of fault displacements estimated farther south in the Maritime provinces of Canada (Waldron *et al.* 2015). The oceanic domains and the continental margin domains that we interpret in this paper have thus been offset relative to each other. However, because the strike-slip faults are orogen-parallel, the orogenic architecture described below is fairly continuous along-strike in Newfoundland. Reconstructing these strike-slip displacements is relevant when reconstructing the detailed paleogeographic evolution of the orogen, but will not significantly modify the 2D evolution that we build as an example application of our orogenic architecture diagram approach in this case study. We will return to this point in the interpretation section.

In the next section we review the geology of Newfoundland from the NW to the SE. We subdivide it in fault-bounded units corresponding to tectonic columns in the orogenic architecture diagrams (Fig. 4).

Laurentian Units (CPS)

Western Newfoundland comprises a ~60 km-wide stack of west-verging thrust slices, of which the Laurentian continental margin is preserved in the three bottom nappes (Fig. 3, Fig. 4). The Laurentian margin units record a Continental Plate Stratigraphy (CPS) that shows little variability throughout the Appalachian Mountains in Canada and New England (e.g., Wright and Knight 1995; White and Waldron 2022). Facies continuity is a result of the East-West orientation of the Laurentian margin in the early Paleozoic (Domeier 2016; Swanson-Hysell and Macdonald 2017).

External Laurentian CPS. The External Laurentian CPS (EL-CPS) is the lowest structural unit and comprises a crystalline basement with igneous and metamorphic rocks (Long Range Inlier) yielding U-Pb zircon crystallization ages of 1530-985 Ma (Heaman *et al.* 2002). These rocks are correlated to the Pinware terrane in Labrador (Fig. 3) and are likely part of the Grenville Province (Hoffman 1988; Owen 1991; Waldron and Stockmal 1994; Cawood *et al.* 2001; Heaman *et al.* 2002). The crystalline basement is unconformably overlain by the 'autochthonous' continental margin of Laurentia (Cawood *et al.* 2001). The stratigraphy contains coarse basal conglomerates, arkosic sandstones and local mafic volcanic units of the Bateau and Lighthouse Cove formations of the Labrador Group (Waldron *et al.* 2022 and references therein; White and Waldron 2022, and reference therein). The mafic volcanic rocks are chemically identical to mafic dykes (Long Range dykes) that yield U-Pb zircon and baddeleyite ages of 615 ± 2 Ma that intrude the crystalline basement in Labrador (NW of Newfoundland; Fig. 3) (Kamo *et al.* 1989). The mafic volcanic and intrusive rocks are interpreted to form during incipient rifting of the Laurentian margin (Williams and Hiscott 1987; Cawood *et al.* 2001; White and Waldron 2022). The overlying Bradore Formation of the Labrador Group is a clastic sedimentary succession of early Cambrian age (~530-515 Ma based on fossil biozones; White and Waldron 2022 and references therein), which contains detrital zircons with Laurentian provenance (Cawood and Nemchin 2001; Hibbard *et al.* 2006, 2007). Some authors interpret the base of the Bradore formation as representing the rift-drift transition, as the formation does not contain any record of syn-rift igneous activity (e.g., Cawood *et al.* 2001); several authors, on the other hand, place the

transition at the top of the formation, corresponding to the change from siliciclastic to carbonate deposition (e.g., Williams and Hiscott, 1987; White and Waldron 2022).
The rift succession grades upward into transgressive limestones and mudstones (upper Labrador Group, Port au Port Group and St. George Group) that represent carbonate platform and shelf deposits of a passive margin (Hibbard *et al.* 2006). This passive margin sequence spans from the middle Cambrian to the Lower Ordovician (~520-469 Ma fossil ages; White and Waldron 2022 and references therein).
A regional unconformity spanning 469-464 Ma then breaks the sedimentation (St. George unconformity; Waldron 2019; White and Waldron 2022). Then, the Table Head Group records short-lived limestone deposition, locally alternating with conglomerates that rework the underlying platform sequence (Stenzel *et al.* 1990). These limestones grade upward into a fine-grained, Middle Ordovician (~464-460 Ma) siliciclastic turbidite succession (flysch of the Goose Tickle Group) containing undifferentiated ophiolite-derived detritus (e.g., ultramafic debris containing chromite; Stevens 1970; Hiscott 1984; Kerr 2019; White and Waldron 2022). The St. George's unconformity is interpreted as uplift and erosion due to the passage of a forebulge during SE-dipping subduction of the passive margin, and the following succession is interpreted as foreland basin sediments, testifying proximity to the trench (Knight *et al.* 1991; White and Waldron 2022).

Middle Laurentian CPS. The flysch of the External Laurentian CPS is structurally overlain by tectonic slices containing continental margin units, often referred to as 'allochthons' (Williams and Cawood 1989; Stenzel *et al.* 1990; Batten Hender and Dix 2008; White and Waldron 2022) and here named 'Middle Laurentian CPS' (ML-CPS). Their stratigraphy is largely correlative to the 'autochthonous' Laurentian margin they have been thrust upon. It comprises latest Proterozoic mafic units (Skinner Cove formation of ca. 556-550 Ma U-Pb zircon age, McCausland *et al.* 1997; Hodych *et al.* 2004), with alkaline and subalkaline geochemical signature (Baker 1979) and Cambrian clastic rocks (Summerside and Blow Me Down Brook formations), overlain by limestones and shales (Irishtown formation and Cow Head Group) spanning the middle Cambrian-Middle Ordovician (ca. 510-470 Ma; Lacombe *et al.* 2019; White and Waldron 2022). These rocks are interpreted as deeper-water equivalents of units belonging to the autochthonous passive margin succession (James and Stevens 1986; Waldron and Palmer 2000; White and Waldron 2022). This sequence is overlain by coarse-grained siliciclastic turbidites of the Western Brook Pond Group, containing chromite-bearing ophiolite detritus (Stevens 1970; Hiscott 1984; Lindholm and Casey, 1989; White and Waldron 2022; Yan and Casey 2023 and references therein), dated through fossil biozones at ca. 470-465 Ma (Lacombe *et al.* 2019 and references therein). The Middle Laurentian CPS sedimentary units locally occur as blocks in disrupted successions (mélanges) that also contain mafic rocks (Karson and Dewey 1978). These mélanges have gradational contacts with the coherent sedimentary units and may have formed as olistostromes during emplacement of the Middle Laurentian CPS (Lacombe *et al.* 2019). The Middle Laurentian CPS units are folded and duplexed, structures which are attributed to their emplacement on top of the correlative Laurentian-proximal units during the Middle Ordovician (Waldron and Palmer 2000; White and Waldron 2019). However, the absolute timing of deformation remains unconstrained.

The Middle Laurentian CPS margin units are disconformably overlain by the Long Point Group, comprising a thick Upper Ordovician limestone unit (ca. 458-453 Ma graptolite age;

Bergström *et al.* 1974) grading into a coarsening upward sandstone succession reaching Katian (i.e., ca. 453-445 Ma) age and containing volcanic clasts (Stenzel *et al.* 1990; Quinn *et al.* 1999).

Internal Laurentian CPS. East of the Middle Laurentian CPS are several meta-sedimentary units (e.g., Fleur de Lys Supergroup, Corner Brook Lake Belt/Block, Fig. 3), recording medium-grade metamorphic signatures. This Internal Laurentian CPS (IL-CPS) sequence is interpreted as the metamorphic equivalent to the 'autochthonous' External Laurentian CPS (Williams 1995; Waldron and van Staal 2001; de Wit and Armstrong 2014), and representing the continental margin of Laurentia that was partly subducted; in the case of the Fleur de Lys Supergroup, the Laurentian margin is interpreted as hyperextended (van Staal *et al.* 2013). In northern Newfoundland, the dextral strike-slip Cabot Fault represents the boundary between the Middle Laurentian CPS in the west and the Internal Laurentian CPS metamorphic units (Fleur de Lys Supergroup) in the east. Farther south, the metasedimentary units of the Internal Laurentian CPS (Corner Brook Lake Block) are separated from the carbonate sequence of the External Laurentian CPS by a (probably) normal fault (Cawood *et al.* 1996), and the Cabot Fault represents their eastern boundary (Fig. 3). In central-western Newfoundland, the Cabot Fault, together with the Baie Verte-Brompton Line (see description below) (Fig. 3), define a strike-slip fault system that separates the western part of Newfoundland comprising the Laurentian CPS units from the eastern domain (e.g., Brem *et al.* 2007; van Staal and Barr 2012). The structure crosscuts a 455 ± 12 Ma syn-tectonic pegmatite dyke, and a 446 ± 1 Ma granodiorite constrains minimum timing of deformation along this fault zone (Brem *et al.* 2007).
In northern Newfoundland, east of the Cabot Fault, the metamorphic units are represented by the Fleur de Lys Supergroup (Fig. 3), which underlies a Proterozoic crystalline basement with Grenvillian affinity (Cawood *et al.* 1996; Skulski *et al.* 2010). The Fleur de Lys Supergroup is made up of a basal unit (Birchy Complex) comprising metamorphosed magmatic rocks (serpentinite, actinolite/tremolite schist, amphibolite, metabasalt, metagabbro yielding a U-Pb zircon age of 558.3 ± 0.7 Ma; Hibbard 1983; Cawood *et al.* 1996; van Staal *et al.* 2013). The basal unit is unconformably overlain by a metasedimentary cover sequence with basal metaconglomerates, and mostly comprising psammites and semipelitic schists, with minor calc-schists and marble (e.g., van Staal *et al.* 2013; Strowbridge *et al.* 2022 and references therein; White and Waldron 2022; Hashmi 2023; Scorsolini *et al.* 2025). No biostratigraphic age exists for these metasediments, but they are stratigraphically correlated to unmetamorphosed equivalents of the Laurentian margin (e.g., White and Waldron 2022). Eclogites in the crystalline basement yield a multistage metamorphic history with underplating at ~2.7 GPa and ~640 °C and a metamorphic peak at ~1.5 GPa and ~800 °C during exhumation (Scorsolini *et al.* 2025). Metamafic and metapelitic rocks of the Fleur de Lys Supergroup yield pressures of 6.7-11.2 kbar and temperatures of 315-600 °C (Willner *et al.* 2022). Metamorphic ages are scarce, mostly hindered by younger deformation and overprinting (Willner *et al.* 2022). However, dating of basement eclogites (U-Pb zircon, Lu-Hf, Sm-Nd and Rb-Sr multimineral isochrons), granites (U-Pb zircon), and mafic schists ($^{40}Ar/^{39}Ar$ white mica and amphibole) beneath the metasedimentary units yield metamorphic ages of ca. 483-460 Ma, constraining regional metamorphism to the Lower-Middle Ordovician (Castonguay *et al.* 2014; de Wit and Armstrong 2014; Willner *et al.* 2015; Strowbridge *et al.* 2022). This is broadly consistent with peak metamorphism inferred at ca. 466 Ma from a U-Pb monazite age in a paragneiss (van Staal *et al.* 2007). Overlying units of Upper Ordovician-Silurian ages lack metamorphism and deformation (Dubé *et al.* 1996) and confirm the metamorphic ages must be Middle Ordovician.

The Corner Brook Lake Block, in central-west Newfoundland (Fig. 3), is historically reported as a correlative of the Fleur de Lys Supergroup (e.g., White and Waldron 2022). It is made up of a Proterozoic basement and latest Neoproterozoic gneissic units (e.g., the Lady Slipper pluton of 555 +3/-5 Ma U-Pb zircon age), overlain by quartz-rich metasedimentary rocks, marbles, limestones conglomerates and calc-schists (Cawood *et al.* 1996, 2001; Lin *et al.* 2013). Similarly to the Fleur de Lys Supergroup, no biostratigraphic ages exist for the Corner Brook Lake Block. Metamorphic conditions reached amphibolite to eclogite facies (Lin *et al.* 2013), and results from U-Pb geochronological studies on zircons show Pinwarian ages (i.e., ca. 1.5 Ga) but an apparent lack of Grenvillian signature (i.e., ca. 1 Ga ages) in its crystalline basement (Cawood *et al.* 1996; Lin *et al.* 2013 and references therein), although such signature is present in the overlying sedimentary cover (Cawood and Nemchin 2001; Lin *et al.* 2013). Furthermore, the lithologies of the Corner Brook Lake Block lack any Ordovician metamorphism, but rather U-Pb on zircon, metamorphic monazite and rutile and $^{40}Ar/^{39}Ar$ on hornblende and muscovite reveal Silurian metamorphism (i.e., ca. 437-420 Ma; Cawood *et al.* 1994; Lin *et al.* 2013). Lin *et al.* (2013) thus interpreted this metamorphic unit as being a Laurentian block transported from the north by dextral convergence.

Coastal Complex

Structurally above the southwestern Middle Laurentian CPS units are the Coastal Complex and the Bay of Islands Ophiolitic Complex, which are the two structurally highest units of the west-verging thrust stack (Fig. 4b). The two complexes are geographically close (Fig. 3), and several authors report an igneous contact between them, with the younger Bay of Islands Ophiolite intruding into lithologies of the Coastal Complex (Karson and Dewey 1978; Karson *et al.* 1983; Suhr and Cawood 1993, 2001). This intrusive relationship is not accepted by all authors (e.g., Jenner *et al.* 1991, who argue for a structural contact).

The Coastal Complex consists of a narrow 5-10-km wide, highly deformed, thrusted, and variably metamorphosed sequence of foliated gabbro, amphibolite, tholeiitic pillow lavas and volcaniclastic rocks (Jenner *et al.* 1991; Suhr and Edwards 2000; Kerr 2019; Waldron 2019). No protolith or metamorphic ages are available for these metamorphosed ocean floor rocks. The deformed lithologies of the Coastal Complex were then intruded by leucocratic rocks with arc signature (trondhjemites, diorite, quartz-diorites; Casey *et al.* 1985; Jenner *et al.* 1991; Kerr 2019) with U–Pb zircon ages spanning 514-503 Ma (Yan and Casey 2022), providing a minimum age for the deformation, metamorphism, and thrusting of the oceanic floor lithologies of the Complex. Geochemistry of the basalts and diabases and of the trondhjemites intruding the Coastal Complex indicate arc tholeiitic, suprasubduction zone signatures (Jenner *et al.* 1991). The Coastal Complex is thrust atop undifferentiated deep-water sediments of the Middle Laurentian CPS nappes (White and Waldron 2019; Yan and Casey 2022).

Ophiolites

Bay of Islands Ophiolite. The Bay of Islands Ophiolite Complex is a ~25 km wide klippe located <5 km east-southeast of the Coastal Complex (Fig. 3) and preserves a coherent section of oceanic lithosphere containing, from bottom to top, harzburgite tectonite, peridotite, pyroxenite, foliated and isotropic gabbro, plagiogranite intrusions with a U–Pb zircon age of 488.3 ± 1.5 Ma (Yan and Casey 2020), sheeted dykes, and pillow basalts (Casey and Karson 1981; Casey *et al.* 1983; Yan and Casey 2020). A metamorphic sole at the base of the mantle section comprises uppermost garnet-clinopyroxene granulite and garnet-clinopyroxene amphibolite, a middle unit of common amphibolites with U–Pb zircon ages of 489–484 Ma (Yan and Casey 2023) and U–Pb titanite ages of 486 ± 7 Ma and 484 ± 5 Ma (Fournier-Roy *et al.* 2024) and a lower greenschist unit (Fournier-Roy *et al.* 2024; Yan *et al.* 2025). Geochemistry indicates the upper part of the sole formed from mafic rocks with a MORB affinity (Fournier-Roy *et al.* 2024). Biotite and muscovite in a biotite-garnet metasedimentary schist found within amphibolite facies portions of the sole yielded ages of 480 ± 2 and 479 ± 2 Ma, respectively, recording cooling below ~ 340°C and thus exhumation of the high-grade sole by that time (Yan *et al.* 2025). Greenschist-facies metasedimentary rocks from the middle unit yield youngest U-Pb detrital zircon age of ca. 490 Ma, which is interpreted as the maximum depositional age (Fournier-Roy *et al.* 2024); the detrital zircon analyses also exhibit a subtle peak in Proterozoic ages and a dominant peak in Cambro-Ordovician ages, pointing to contributions from Laurentian lithologies and a Cambro-Ordovician arc, respectively (Fournier-Roy *et al.* 2024). Because of the overlap in metamorphic titanite and detrital zircon ages, Fournier-Roy *et al.* (2024) interpreted the metasedimentary rocks as representing trench-fill sediments, which were buried almost immediately after deposition and accreted as a successive slice below older slices of the metamorphic sole; deposition and subduction were thus nearly coeval. The Bay of Islands Ophiolite has a supra-subduction zone (SSZ) geochemical signature (Elthon 1991) and is interpreted to have formed by spreading above a subduction zone (Cawood and Suhr 1992; Yan and Casey 2023; Cawood *et al.* 2024; Fournier-Roy *et al.* 2024).

The Bay of Islands Ophiolite is thrust over Middle Ordovician (ca. 470-465 Ma) turbiditic sequences of the Middle Laurentian CPS (Yan and Casey 2023) and is unconformably overlain by a Middle Ordovician (Darriwilian, ca. 467-458 Ma) succession of sedimentary breccia containing ophiolite-derived clasts (red jasper, basalt, diabase clasts, with minor trondhjemite, gabbros, and serpentinized ultramafic clasts), olistostromal shale/mudstone, and coarse red calcareous sandstone named Crabb Brook Group (Casey and Kidd 1981). These are interpreted as a syn-obduction sedimentary cover and, together with the foreland basin deposits, they show that the complex emerged by 467 Ma.

Another ophiolitic complex is thrust on top of sedimentary Middle Laurentian CPS units in NW Newfoundland (St. Anthony Complex; Dallmeyer 1977; Jamieson 1981) (Fig. 3) and comprises peridotite and an underlying metamorphic sole of metagabbro, granulite, amphibolite, greenschist, and undeformed volcanic rocks at its base (Jamieson 1981). Hornblende ^{40}Ar/^{39}Ar ages in amphibolites yield 480 ± 5 Ma ages, and metamorphic zircons in the aureole return U-Pb ages of ca. 495 Ma (Jamieson 1988). Correlations and interpretations of the geological history of this complex are difficult and more data is needed.

Baie Verte ophiolites. East of the Internal Laurentian CPS in northwestern Newfoundland (i.e., the Fleur de Lys Supergroup), oceanic units are juxtaposed with Internal Laurentian CPS metasediments along a strike-slip fault, the Baie Verte-Brompton Line (e.g., Williams *et al.* 1982; Waldron *et al.* 2015) (Fig. 3). The Baie-Verte Brompton Line reactivates a crustal-scale, oblique-dextral ductile shear zone (e.g., Goodwin and Williams 1996).

Oceanic units exposed east of the Baie Verte-Brompton Line are deemed the Baie Verte Oceanic Tract (Hibbard 1983; van Staal *et al.* 1998, 2007). This tract is ~5 km wide and includes ultramafic rocks (harzburgite, pyroxenites), gabbros yielding U-Pb zircon ages of 489 +3/-2 Ma, mafic dykes, plagiogranites yielding U-Pb zircon ages of 490 ± 4 Ma, and boninites (e.g., Dunning and Krogh 1985; Cawood *et al.* 1996; Skulski *et al.* 2010). Volcanic rocks have MORB, IAT and OIB geochemical signatures (Swinden *et al.* 1997). Units of the Baie Verte Oceanic Tract all contain elements of oceanic lithosphere and yield similar ages to the Bay of Islands Complex and are therefore interpreted as ophiolites with similar ages to the BOIC (Swinden *et al.* 1997; van Staal *et al.* 2014). The Baie Verte Oceanic Tract units are unconformably overlain by volcano-sedimentary rocks (Snooks Arm Group and correlatives; Skulski *et al.* 2010). Both the Baie Verte units and its volcano-sedimentary cover show polyphase deformation, with the first deformation phase being only recorded by the Baie Verte ophiolites. The overlying volcanosedimentary cover comprises a basal conglomerate with ophiolite-derived (gabbro, basalt and rare boninite) clasts, tholeiitic to calc-alkaline basalts, felsic tuffs of ca. 470 Ma (Skulski *et al.* 2017), tuff breccias, rhyolites of 492.6 ± 0.6 Ma (U-Pb zircon age; Conliffe and Hamilton 2022) and sedimentary rocks including wackes, siltstones, and shales of Early Ordovician age (Williams 1992; Skulski *et al.* 2010). A U-Pb zircon age of a gabbro sill underlying the sequence, and an unpublished felsic tuff age in the sequence, constrains sedimentary deposition between ca. 483 Ma (Ramezani 1992) and 467 Ma, respectively (Skulski *et al.* 2010). Furthermore, the ca. 492 Ma age of the rhyolite shows that, in some areas (e.g., the Grand Lake area in central-west Newfoundland, where the rhyolite was dated), the ophiolitic units and their volcanic cover overlap in age (Conliffe and Hamilton 2022). This volcano-sedimentary sequence is interpreted as an arc correlated to a magmatic arc preserved farther south (i.e., the Notre Dame Arc, described below; Brem *et al.* 2007).

Lush's Bight ophiolite (northern Newfoundland). In northwestern Newfoundland, the post-Ordovician, dextral strike-slip Green Bay Fault exhibits minor displacement (Coyle and Strong 1986; Ritcey *et al.* 1995; Waldron *et al.* 2015) and separates the Baie Verte ophiolites from other units of oceanic affinity to the east (Fig. 3). These oceanic rocks are commonly grouped as the Lush's Bight Oceanic Tract (Kean *et al.* 1995; Szybinski 1995; van Staal *et al.* 2007; van Staal and Barr 2012). The Lush's Bight units span a ~20 km-wide zone and their relationships with underlying lithologies are obscured by later faults and igneous intrusions (e.g., Zagorevski *et al.* 2024). The Lush's Bight units dominantly comprise plagiogranites and pillowed lavas of island arc tholeiitic to boninitic affinity, overlain by epiclastic rocks, with minor ultramafic and gabbro sills and sheeted dykes (Szybinski 1995; Swinden *et al.* 1997; van Staal and Barr 2012). The magmatic rocks have not been dated but are interpreted as middle-late Cambrian (510-501 Ma; e.g., van Staal *et al.* 2007, 2012) based on crosscutting relationships with younger calc-alkaline dykes ($^{40}Ar/^{39}Ar$ hornblende ages of 504-495 Ma; Szybinski 1995 and references therein). Recently, Yan and Casey (2022) obtained a U-Pb zircon age of 504.3 ± 1.8 Ma for a plagiogranite intrusion (Twillingate granite; Fig. 3) cross-cutting the mafic volcanic sequences correlative to the Lush's Bight tract, which may provide a minimum age for the oceanic crust. Geochemistry of the Lush's Bight rocks reveals boninite and island arc tholeiite signatures, with some rocks in the upper part of the sequence yielding MORB signatures (Szybinski 1995; Swinden *et al.* 1997). This is interpreted as a suprasubduction zone setting (Szybinski 1995). The geochemistry of cross-cutting calc-alkaline dykes exhibit a considerable contribution from continental lithosphere; correlation with modern geochemical equivalents led authors to interpret the dykes as deriving from assimilation of continental crust by a mantle-derived magma, and thus to indicate the presence of continental crust at depth (Szybinski 1995; Swinden *et al.* 1997 and references therein). Therefore, the Lush's Bight rocks are interpreted to have been emplaced onto continental crust and then crosscut by continental crust-derived melts (Szybinski 1995; Swinden *et al.* 1997). However, this signature could have also been acquired due to close proximity to continental crust or from subducted Laurentian sediments. Based on their internal stratigraphy, the Lush's Bight units classify as ophiolites in our orogenic architecture classification scheme.

The Lush's Bight ophiolite is observed in fault contact (Szybinski 1995; Swinden *et al.* 1997) with overlying bimodal volcanic rocks (Upper Western Arm Group and Catchers Pond Group), which contain high proportions of felsic pyroclastics and epiclastics, chert, limestone and limestone breccia (Szybinski 1995; Swinden *et al.* 1997). Volcanic ages span 479 ± 4 to 465 ± 1 Ma (U-Pb zircon age and $^{40}Ar/^{39}Ar$ hornblende age of tuffs, respectively; Szybinski 1995), consistent with limestone breccias that are interlayered within the volcanic units and contain fossils indicating Lower-Middle Ordovician deposition (Szybinski 1995 and references therein). The mafic rocks have calc-alkaline signatures (Swinden *et al.* 1997) and felsic rocks show a Nd concentration and Sm/Nd ratios indicative of contamination from continental crust, which is attributed to proximity to the Laurentian continental margin (Szybinski 1995). The volcano-sedimentary sequence is interpreted as renewed volcanism in an island arc setting (Szybinski 1995; Swinden *et al.* 1997), which we here correlate to the volcano-sedimentary units similarly overlying the Baie Verte ophiolites, and to the Notre Dame magmatic arc farther to the south (see next section).

Dashwoods Microcontinent and Notre Dame Arc (Southern Newfoundland)

East of the Cabot-Baie Verte-Brompton strike-slip fault system in southwestern Newfoundland, rocks are mostly continental in nature (Fig. 3). These continental units occupy a 40-km wide zone and are thought to have been located paleogeographically eastward of the oceanic basin that produced the ophiolitic Lush's Bight and Coastal Complex OPS units described above. Only restricted, variably metamorphosed ultramafic units (Lissenberg *et al.* 2006) and one oceanic complex (Fig. 3, Long Range mafic-ultramafic Complex of van Staal *et al.* 2007) comprising lower crustal and mantle rocks – gabbro, trondhjemite, and peridotite tectonite (Zagorevski *et al.* 2024) – are reported in southwest Newfoundland. These units are intruded by Late Cambrian-Early Ordovician plutons (e.g., Dubé *et al.* 1996; Lissenberg *et al.* 2006), but lack any absolute age constraints. Because of their position directly east of the Baie Verte-Brompton Line, these oceanic units have been correlated to units of similar lithologies and in similar structural positions in the north of Newfoundland, either to the Lush's Bight ophiolites (Lissenberg *et al.* 2006; van Staal *et al.* 2007; Zagorevski *et al.* 2024) or the Baie Verte ophiolites (e.g., Willner *et al.* 2022), or to oceanic units farther east (Annieopsquotch Tract, described below; e.g., Dunning and Chorlton 1985). However, as these ultramafic units are intruded by late Cambrian-Early Ordovician plutons, correlations with the Early Ordovician Annieopsquotch Tract were later disregarded (e.g., Lissenberg *et al.* 2006).

Dashwoods microcontinent. In the 40-km wide zone east of the Cabot-Baie Verte Brompton fault system, metasedimentary rocks are found that are interpreted to make up the Dashwoods microcontinent (Waldron and van Staal 2001) (Fig. 3). Such lithologies are predominantly exposed in southwestern Newfoundland, though some similar metasediments can also be found along strike in the northeast (e.g., van Staal *et al.* 2007 and references therein). These are continent-derived metasedimentary units that comprise metaclastic rocks, marble, migmatized paragneiss yielding U-Pb monazite ages of 466.5 ± 1.8 Ma (van Staal *et al.* 2007), and garnet-muscovite schists yielding U-Pb monazite ages of ca. 460 Ma (McNicoll *et al.* 2007, personal communication reported in Lin *et al.* 2013; Waldron and van Staal 2001 and references therein). Both monazite and zircon ages are interpreted as the ages of peak regional metamorphism, which reached granulite facies (van Staal *et al.* 2007). Although no Precambrian basement is exposed in this southern region, detrital zircon recovered from the metasedimentary units shows a Laurentian signature, so that these units are interpreted as correlative to the metamorphic sedimentary units of the Laurentian continental margin in Newfoundland (i.e., Fleur de Lys Supergroup; Currie *et al.* 1992; Waldron and van Staal 2001; Brem *et al.* 2007) or as correlatives to western Ireland Laurentian units (e.g., Hodgin *et al.* 2022; Zagorevski *et al.* 2024).

Notre Dame Arc. The 40-km wide zone east of the Cabot-Baie Verte Brompton fault system is dominated, both in its southern and northern parts, by felsic intrusions, with minor diorites and gabbros, which, collectively with volcano-sedimentary units overlying the Baie Verte ophiolites, are called the Notre Dame Arc (e.g., van Staal *et al.* 2007) (Fig. 3). The plutons lie ~60 km east of the Bay of Islands ophiolite (Fig. 3) and intrude continental metasedimentary and oceanic units, exposed in southwestern and northern Newfoundland, respectively (Fig. 3). The intrusions thus constrain a minimum age for metamorphism of the sedimentary package (Hodgin *et al.* 2022 and references therein). The oldest plutons are pre-tectonic, contain mafic enclaves, and are metamorphosed to high grade (locally up to granulite facies; van Staal *et al.* 2007). They are exposed in southwest Newfoundland, where they intrude the metasedimentary units, the Long Range Complex and related minor ultramafic rocks. U-Pb zircon ages of felsic intrusive rocks (tuffaceous schist, tonalitic orthogneiss, and granodiorite) range between 493-489 Ma (Dubé *et al.* 1996; van Staal *et al.* 2007). Along with the volcano-sedimentary units (Snooks Arms Group and correlatives) overlying the Baie Verte ophiolites, this first pulse of magmatism can be bracketed between ca. 493 and 473 Ma (e.g., van Staal *et al.* 2007). A second pulse of magmatism, intruding both the metasedimentary units and older intrusions, was more widespread in southwest and north Newfoundland, and ranges in ages between 469 and 459 Ma (tonalite, granodiorite, and charnockite U-Pb zircon ages; Dubé *et al.* 1996; van Staal *et al.* 2007). These plutons are metamorphosed up to amphibolite facies and are interpreted as syn-tectonic (van Staal *et al.* 2007).

The 493-489 Ma *and* the 469-459 Ma felsic intrusive suites both contain inherited zircons and geochemical signatures indicating intrusion into (old) continental crust with a Laurentian signature (i.e., ca. 600 and 850-1600 Ma) (van Staal *et al.* 2007; Whalen *et al.* 1997). Therefore, van Staal *et al.* (2007) interpreted these two magmatic phases as arc magmatism, built on continental crust. In contrast, Hodgin *et al.* (2022) attributed the Laurentian signature to subducted detritus which does not require the presence of a continental basement. We note that zircon inheritance from subducted sediment is less likely to contribute to a significant signature, and that subducted zircon is less likely to preserve its original signature (e.g., van Staal *et al.* 2007; Kröner 2010 and references therein; Tapster *et al.* 2014).

The timing of metamorphism of late Cambrian-Middle Ordovician intrusions is not well constrained but is inferred to occur at the same time as metamorphism of the units they intrude (i.e., Middle Ordovician). Upper Ordovician-Devonian sedimentary successions that contain deformed felsic clasts at their base (van Staal *et al.* 2007) are not themselves deformed or metamorphosed, which further constrains peak deformation and metamorphism of the underlying units to the Middle Ordovician (Waldron and van Staal 2001). Furthermore, a U-Pb zircon age of 459.4 +3/-1.5 Ma obtained for a granulite facies meta-granite (Currie *et al.* 1992, recalculated by van Staal *et al.* 2007) is interpreted as the age of peak metamorphism (Brem *et al.* 2007; Currie *et al.* 1992) and indicates that magmatism was syn-tectonic.

Collectively, these late Cambrian-Middle Ordovician plutons are interpreted as a continental magmatic arc, the Notre Dame Arc (e.g., Whalen *et al.* 1997; van Staal *et al.* 2007). The geochemical signature and inherited zircons in the magmas, which were derived from a Precambrian basement, and the presence of metasedimentary units correlated to the Laurentian continental margin, led several authors to infer that a Dashwoods microcontinent had rifted off the Laurentian margin in the Cambrian and then reaccreted during the Early-Middle Ordovician (Waldron and van Staal 2001). The Notre Dame Arc is therefore thought to be in part built on this microcontinent.

Although all intrusions of the Notre Dame Arc lie to the east of the Cabot-Baie Verte Fault, one restricted (< 2 km in width) intrusive unit in northern Newfoundland, west of the Cabot Fault, is correlated to it (Coney Head Complex; Williams 1977). The Coney Head Complex structurally overlies units of the Middle Laurentian CPS to the west (Williams 1977; Dunning 1987b; Kerr and Knight 2004) and comprises a basal mélange with mafic clasts (gabbro, serpentinite, ultramafic rocks, greenschist) and mafic to intermediate intrusions (tonalites of 474 ± 2 Ma U-Pb zircon age, diorites, gabbro), intruded by Silurian microgranite (Williams 1977; Dunning 1987b). No geochemical analyses have been carried out on this unit. Because of its age and lithological correlations to volcano-sedimentary units farther east, the Coney Head Complex is interpreted as representing an intraoceanic island arc (Dunning 1987b) associated with the Bay of Islands forearc Ophiolite (van Staal and Dewey 2023).

Upper Ordovician magmatism in (south)western Newfoundland is limited, but one such restricted volcano-sedimentary group (Windsor Point Group, ~2 km wide; Fig. 3) unconformably overlies older magmatic units (Dubé *et al.* 1996). The Windsor Point Group comprises felsic and mafic volcanic rocks (453 +5/-4 Ma rhyolite U-Pb zircon age), conglomerates, greywackes, and siltstones (Dubé *et al.* 1996). No geochemical analyses are available for this group, but Dubé *et al.* (1996) related the volcanic rocks to an extensional event, because of the extension-dominated control observed in the distribution of the conglomerate facies. Furthermore, Brem *et al.* (2007) reported a 446 ± 1 Ma U-Pb zircon age for a restricted granodiorite sheet in southern Newfoundland, for which no geochemical analyses are available.

A Silurian, Llandovery-to-Wenlock bimodal magmatic pulse is more widespread in northern Newfoundland, constrained by 440-427 Ma granodiorite, quartz-diorite, granite and gabbro U-Pb zircon ages (Cawood *et al.* 1996; Whalen *et al.* 1987, 2006; Lissenberg *et al.* 2006; Brem *et al.* 2007). Geochemical analyses reveal an arc signature for felsic intrusions dated 440-435 Ma (Whalen *et al.* 2006), which some authors interpret as representing another phase of Notre Dame Arc magmatism (van Staal *et al.* 2007). A mixed arc- and non-arc- (e.g., post-collisional, within-plate) signature is recorded by younger (ca. 432-427 Ma) bimodal magmatic rocks, which Whalen *et al.* (2006) interpreted to result from slab break-off. Silurian magmatism is coeval with a Wenlock volcano-sedimentary succession (Springdale Group; Fig. 3, Fig. 4) comprising arc to bimodal subaerial magmatic rocks (429 +6/-5 Ma U-Pb zircon age on rhyolite; Chandler *et al.* 1987), polymictic conglomerate with clasts derived from the underlying rocks, and red sandstones (Zagorevski *et al.* 2008). The Springdale Group overlies units of Dashwoods, Lush's Bight, and the Notre Dame Arc, as well as those of the Annieopsquotch Tract (described in the next section), with a sub-Silurian unconformity separating this succession from older rocks (Dunning *et al.* 1990). The Springdale

Group is interpreted as an overlap sequence, with within-plate magmatism attributed to a mantle-rooted thermal anomaly under thickened continental crust (Chandler *et al.* 1987; Whalen *et al.* 2006).

Annieopsquotch Tract

To the east, structurally beneath the metasedimentary and igneous rocks of the Dashwoods microcontinent and Notre Dame Arc and the oceanic units of the Lush's Bight ophiolite, four mafic and felsic tectonic slices comprise a ~10-km wide, NW-dipping thrust stack (Zagorevski *et al.* 2008). Previously called the Annieopsquotch Accretionary Tract (van Staal *et al.* 1998), herein we call it the Annieopsquotch Tract as this complex is not derived from the lower plate as the term 'accretionary' might imply (Fig. 3). The western contact of this complex is an oblique sinistral NW-dipping shear zone made up of amphibolites and mylonites called the Lloyd's River Fault Zone (Lissenberg and van Staal 2002). Along this fault, oceanic rocks of the Annieopsquotch Tract are thrust beneath igneous and metasedimentary rocks of the Dashwood microcontinent and Notre Dame arc to the west (Lissenberg and van Staal 2002; Lissenberg *et al.* 2005b). This fault was active from ca. 471 Ma ($^{40}Ar/^{39}Ar$ hornblende age of an amphibolite) to ca. 459 Ma (U-Pb zircon age of a syn-kinematic – with respect to the fault – intrusion) (Lissenberg *et al.* 2005b).

Annieopsquotch Ophiolite Belt. The structurally highest and westernmost unit of the Annieopsquotch Tract below the Lloyd's River Fault Zone is the Annieopsquotch ophiolite belt (Dunning 1981) that is made up of gabbro sills, mafic cumulates, sheeted dykes, and plagiogranitic bodies yielding U-Pb zircon ages of 477.5 +2.6/-2 and 481 +4/-2 Ma (Dunning and Krogh 1985) and pillow lavas. Magmatic rocks show tholeiitic and MORB signatures, with negative Nb anomaly indicative of a suprasubduction zone signature (Lissenberg *et al.* 2005a, b; Zagorevski *et al.* 2014). The Annieopsquotch ophiolite belt – as well as the Lloyd's River Fault Zone – is crosscut by (deformed) plutons of mafic to granodioritic composition with crystallization and/or deformation ages ranging from 464 to 459 Ma (Lissenberg *et al.* 2005a). Similar geochemical signature and ages of these plutons led to correlations with the Notre Dame Arc (Lissenberg *et al.* 2005a).

Lloyd's River Complex. The sinistral transpressive, greenschist to amphibolite facies shear zone Otter Brook shear zone (Lissenberg *et al.* 2005a) separates the Annieopsquotch ophiolite belt from the structurally underlying oceanic Lloyd's River Complex to the east. The Otter Brook shear zone comprises mylonites, phyllonites, and micaschists with a NW-dipping foliation, deformed rhyolites, micaschists, and amphibolites (Lissenberg *et al.* 2005a; Zagorevski and van Staal 2002; Zagorevski *et al.* 2006). The Lloyd's River Complex comprises gabbro (473 ± 3.4 Ma U-Pb zircon age; Zagorevski *et al.* 2006), anorthosite, sheeted diabase dykes, and pillow lavas with a tholeiitic geochemical signature that is distinct from the overlying Annieopsquotch ophiolite belt (Lissenberg *et al.* 2005a; Zagorevski *et al.* 2006). The Otter Brook shear zone, Annieopsquotch ophiolite belt, and Lloyd's River Complex are all intruded by syn-kinematic – with respect to the shearing – mafic rocks (gabbro) and granodiorites (468 ± 2 Ma U-Pb zircon age; Lissenberg *et al.* 2005a) thereby constraining a minimum age of emplacement of the Lloyd's River Complex below the Annieopsquotch ophiolite belt by 468 Ma. Both the Annieopsquotch ophiolite belt and the Lloyd's River Complex are interpreted as the deformed remnants of upper plate ocean floor.

The Lloyd's River Complex is bounded to the SE by brittle-ductile thrust faults (Lissenberg *et al.* 2005b) that juxtapose it against bimodal volcaniclastic rocks of the two deepest structural units of the Annieopsquotch Tract. No radiometric dates of these faults are available.

Buchans Group. The Buchans Group lies east of, and structurally below, the Lloyd's River Complex, and comprises pillow basalts, breccia, diabase, dacites (463 ± 4 Ma U-Pb zircon age; Zagorevski *et al.* 2016), granodiorites (467 ± 1 Ma U-Pb zircon age; Whalen *et al.* 2013), tuff and rhyolites yielding U-Pb zircon ages of 473 +3/-2 Ma and 465 ± 4 Ma (Dunning *et al.* 1987a; Zagorevski *et al.* 2016), felsic tuff yielding U-Pb ages of 473.4 ± 1.2 Ma and 462 ± 4 Ma, and cherts (Dunning *et al.* 1987a; Zagorevski *et al.* 2006; 2016). Fossils recovered from carbonate clasts within the breccia corroborate the Lower-Middle Ordovician age for the Buchans Group and indicate provenance from Laurentia (Nowlan and Thurlow 1984). Geochemical and isotopic characteristics of the felsic and mafic volcanic rocks indicate contributions from continental material, leading Zagorevski *et al.* (2006) to interpret the Buchans Group as a continental magmatic arc. Detrital zircon U-Pb ages and Lu-Hf isotopic signatures in sedimentary rocks of the Buchans Group yield characteristics like sedimentary units of the continental Laurentian margin farther to the west, i.e., Fleur de Lys Supergroup (Willner *et al.* 2014), which indicate that this unit was located close to the continental margin of Laurentia. Structural relationships and geochemical analyses of the Buchans Group led Lissenberg *et al.* (2005b) to posit 467 Ma as a minimum age of its westward accretion beneath the Lloyd's River Complex.

In northern Newfoundland, the Buchans Group is correlated to the Robert's Arm Group (also called Robert's Arm belt; Dunning *et al.* 1987a; Bostock 1988; Swinden *et al.* 1997; Zagorevski *et al.* 2006; Zagorevski and McNicoll 2012; Fig. 3). This belt is made up of fault-bound units comprising mafic and felsic rocks interleaved with shale, chert and greywacke (Dunning *et al.* 1987a; Bostock 1988; Zagorevski and McNicoll 2012). The magmatic rocks comprise pillow basalts, gabbros, mafic volcaniclastic rocks, andesites, granodiorite, lapilli tuff of U-Pb zircon age of 467 ± 4 Ma, rhyolites of U-Pb zircon age of 473 ± 2 Ma and rhyolite breccias of U-Pb zircon age of 466 ± 4 Ma (Dunning *et al.* 1987a; Bostock 1988; Zagorevski and McNicoll 2012). Felsic rocks have peri-Laurentian inherited zircon signatures, and basalts exhibit distinct calc-alkaline and tholeiitic geochemical signature, of which the tholeiitic one shows crustal influence (Bostock 1988; Zagorevski and McNicoll 2012). The tholeiitic basalts have been correlated to the Beothuk Lake Group, which is described in detail below (Zagorevski and McNicoll 2012). Basalts of the easternmost fault-bound unit of the belt show an alkaline signature which is unique and distinct from other mafic rocks in central Newfoundland, and for this reason Zagorevski and McNicoll (2012) interpret this restricted unit as an accreted seamount.

Beothuk Lake Group. The Buchans Group is juxtaposed against the structurally lowest and easternmost Beothuk Lake Group (previously called the Red Indian Lake Group) along a seismically imaged km-scale fault (Thurlow *et al.* 1992). The Beothuk Lake Group contains the youngest rocks of the Annieopsquotch Tract (Lissenberg *et al.* 2005a; Zagorevski *et al.* 2006). It comprises pillow basalts (MORB to IAT to andesitic composition) associated with red shale, jasper, limestone, diabase, gabbro, and plagiogranites intruding mafic rocks (U-Pb zircon age of 464.8 ± 3.5 Ma; Zagorevski *et al.* 2006), and felsic tuff. This sequence is overlain by a volcanogenic conglomerate (467 ± 4 Ma U-Pb zircon age interpreted as its maximum deposition age; Coombs *et al.* 2012) and hematized calc-alkaline pillow basalts interlayed with tuffs yielding U-Pb zircon ages of 465-462 Ma, rhyolites, volcaniclastic sandstone, shales, and cherts (Zagorevski *et al.* 2006). Geochemical signatures of the mafic units indicate a volcanic arc and back-arc setting for the tholeiitic basalts and a continental arc setting for the overlying calc-alkaline basalts (Zagorevski *et al.* 2006). Inherited zircons in the volcanic clasts of the conglomerate and tuffs (Zagorevski *et al.* 2006; Coombs *et al.* 2012) indicate contribution from Laurentian continental rocks (i.e., inherited zircon ages ranging between 2.8 Ga and 500 Ma; Coombs *et al.* 2012), although a basement is nowhere exposed.

The Beothuk Lake Group is thrust southeastward on top of magmatic units with exotic affinity (see next section) (Fig. 3) along the Beothuk Lake Line (Slack *et al.* 2024, previously called the Red Indian Line, Williams *et al.* 1988). Its trace is locally marked by highly tectonized Upper Ordovician black shale mélange (Rogers and Van Staal 2002; Zagorevski *et al.* 2006). Seismic imaging reveals this is a crustal scale structure (van der Velden *et al.* 2004). The black shale mélange is interpreted as syn-collisional, and the associated shear zone is interpreted as having sinistral oblique SSE-directed movement, displacing the Beothuk Lake Group above the exotic units (Zagorevski *et al.* 2008).

Williams *et al.* (1988) initially defined the Beothuk Lake Line based on faunal differences. Brachiopods and trilobites of Celtic affinity occur in the Summerford Group sediments (description below), located just east of the Beothuk Lake Line and structurally below the Annieopsquotch Tract (e.g., Neuman 1984; Williams 1995; Harper *et al.* 2009). These taxa are inferred to originate from Gondwana and lived offshore near island arcs (van Staal *et al.* 1998 and references therein; Harper *et al.* 2009 and references therein) which constrains this group as Gondwana-derived, in contrast to Laurentian fauna to the west of the Line. The conformable Ordovician to Silurian marine sedimentary cover overlying the exotic units to the east of the Beothuk Lake Line (see detailed description in the next section) differs from the unconformable, terrestrial Silurian cover of the Notre Dame Arc and Annieopsquotch Tract to the west. Westward accretion of these exotic units below the Beothuk Lake Group is not precisely dated but it is inferred to have occurred between ca. 455-450 Ma, based on the youngest magmatic age of the Victoria Arc (description below) located east of the Annieopsquotch Tract and thrust beneath it (Lissenberg *et al.* 2005b and references therein). As such, most studies interpret the Beothuk Lake Line (Fig. 2, 3) as the location of the main Iapetus suture between Gondwana- and Laurentia-derived continental and oceanic domains (Williams *et al.* 1988; van Staal *et al.* 1998, 2012; Zagorevski *et al.* 2008).

Penobscot and Victoria CPS Units

Several fault-bounded units are present SE of the Beothuk Lake Line. Herein, we subdivide a northern Newfoundland sequence (transect in Fig. 4a) and a central Newfoundland sequence (transect in Fig. 4b) but group them as a single unit in Fig. 3.

Penobscot and Victoria units in northern Newfoundland (CPS). SE of the Beothuk Lake Line and structurally below the Annieopsquotch Tract, magmatic and sedimentary sequences are interpreted as volcanic arc units. These include the Summerford Group, the Wild Bight Group, and the Exploits Group (Fig. 3). The northernmost is the Summerford Group, a ~5-km wide, fault-bounded unit made up of mafic volcanic rocks (pillow lavas, lapilli tuffs, tuff breccia) interbedded with limestone, arkosic sandstone, mafic-derived sandstones, argillite, felspathic wacke and shale (Jacobi and Wasowski 1985; Zagorevski *et al.* 2012) (Fig. 3). The limestones contain Lower to Middle Ordovician fossils (Tremadocian-Darriwilian; Horne 1970; Elliott *et al.* 1989), and endemic trilobite Celtic fossils interpreted to come from the Gondwana margin; Laurentian fossils are absent. Based on the faunal argument, the Beothuk Lake Line is interpreted as a suture (Harper *et al.* 2009). Basalts are tholeiitic to alkaline and exhibit geochemical characteristics of within-plate and transitional arc environments (Jacobi and Wasowski 1985; Zagorevski *et al.* 2012). The Summerford Group was first interpreted as an accreted seamount (Jacobi and Wasowski 1985) but has recently been correlated to the Victoria Lake Supergroup, interpreted as a volcanic arc (Zagorevski *et al.* 2012). SE of the Summerford Group, a small unit (Dunnage Mélange) contains magmatic blocks with similar geochemical characteristics to the Summerford Group (Wasowski and Jacobi 1985), as well as sedimentary clasts containing fossils indicative of Gondwanan proximity and mostly Lower Ordovician and Cambrian ages (Kay 1976; Hibbard *et al.* 1977; Dean 1985); Zagorevski *et al.* 2012). The Dunnage Mélange is intruded by a porphyritic granite yielding a U-Pb zircon age of 469 ± 4 Ma (Zagorevski *et al.* 2012), which has no correlatives anywhere in this part of Newfoundland. The granite contains inherited zircons derived from Gondwana continental crust, taken as further evidence of peri-Gondwana origin for the mélange unit and the Summerford Group (Zagorevski *et al.* 2012).

South and west of the Summerford Group, the ~20-km wide Wild Bight Group occupies a similar structural position east of the Beothuk Lake Line below the Annieopsquotch Tract (Fig. 3). The Wild Bight Group is subdivided into 'lower' and 'upper' units. The lower unit comprises a bimodal volcanic sequence with pillow lavas (tholeiitic and boninitic composition), pillow breccias, and porphyritic rhyolites; a 486 ± 4 Ma U-Pb zircon age from a mafic dyke (MacLachlan and Dunning 1998b) cross-cutting the felsic breccia, tuff, argillite, and chert constrains a minimum formation age. The lower package occurs as fault-bounded slices intercalated within the upper package, but these (thrust) faults are not well exposed (MacLachlan *et al.* 2001). Geochemical characteristics of the lower mafic and felsic rocks indicate a depleted mantle source and a subduction influence (MacLachlan and Dunning 1998b), interpreted to form in an extensional, suprasubduction zone setting (MacLachlan and Dunning 1998b). The lower Wild Bight Group is correlated to another faut-bounded unit in the same area, the South Lake Igneous Complex (MacLachlan and Dunning 1998b), which is made up of gabbro, gabbroic pegmatite (U-Pb zircon age of 489 ± 3 Ma) and sheeted dykes intruded by diorite and tonalite plutons (U-Pb zircon ages of 489 ± 2 and 486 ± 3 Ma for the plutons, respectively; MacLachlan and Dunning 1998b). The mafic rocks are island arc tholeiites that resemble the older magmatic units of the Wild Bight Group (MacLachlan and Dunning 1998b) and are interpreted to have formed in a suprasubduction zone setting (Zagorevski *et al.* 2010).

The upper Wild Bight Group unconformably overlies the lower unit and is a volcano-sedimentary sequence comprising tuffaceous sandstone, greywacke, polylithic conglomerate, mafic volcanic flows, intermediate-felsic sills and dykes, and argillite and chert. The argillite and chert are interleaved at the top of the succession with pillow basalt sills, pillow basalt breccia, intermediate to felsic sills and dykes and mafic agglomerate (MacLachlan and Dunning 1998a; MacLachlan *et al.* 2001). Diabase and gabbro dykes (472 +2/-9 and 471 ± 4 Ma U-Pb zircon and baddeleyite ages) intrude the whole succession (MacLachlan *et al.* 2001; MacLachlan and Dunning 1998a). Tuffs within the volcaniclastic units yield U-Pb zircon ages of ca. 472 Ma (MacLachlan and Dunning, 1998a) and 458 ± 3 Ma (Zagorevski *et al.* 2008). Clasts of the lower Wild Bight Group occur in volcaniclastic units of the upper sequence, indicating that the upper sequence developed on a substrate made up of the lower Wild Bight Group (MacLachlan *et al.* 2001; MacLachlan and Dunning 1998a). Geochemistry varies from calc-alkaline compositions in mafic flows with crustal contamination, to enriched tholeiitic to alkaline basalts with within-plate affinities in the volcanic sills (MacLachlan and Dunning 1998a). Based on the geochemistry, the upper Wild Bight Group is interpreted to represent a magmatic arc (MacLachlan and Dunning 1998a).

To the east and structurally above the Wild Bight Group (MacLachlan *et al.* 2001; O'Brien *et al.* 1997), and south of the Beothuk Lake Line (e.g., O'Brien *et al.* 1997; McNicoll *et al.* 2006), the ~50-km wide Exploits Group (Fig. 3) comprises a lower magmatic package of porphyritic basalt (island arc tholeiites enriched in REEs; Zagorevski *et al.* 2010), calc-alkaline mafic extrusions, dykes, rhyolites, felsic pyroclastic rocks (486 ± 3 Ma U-Pb zircon age; O'Brien *et al.* 1997) andesitic tuff, diabase intrusions, pillow lavas (tholeiite) and breccia, intercalated with limestones, chert and rare epiclastic turbidites (O'Brien *et al.* 1997, Zagorevski *et al.* 2010). This succession is overlain by a sedimentary package with argillaceous red cherts, oxide-facies iron formation related to the underlying basalts, sandstones, mudstones and conglomerates with Lower Ordovician graptolites and volcaniclastic rocks (O'Brien *et al.* 1997). The sedimentary package is overlain by an upper volcano-sedimentary succession comprising pillow lava and interstitial chert and turbidites yielding a Lower to Middle Ordovician graptolites and conodonts, diorites, subvolcanic dykes, pillow basalt breccias, and massive basalt with intervals of cherts and limestones (O'Brien *et al.* 1997). The mafic rocks in the upper succession yield MORB, transitional tholeiitic, and alkalic geochemical signatures (O'Brien *et al.* 1997). The Exploits Group is interpreted to represent a suprasubduction zone oceanic island arc, expressing a lower magmatic package evolving to arc rifting formation of an oceanic basin. It is correlated to successions with similar geochemistry in the Wild Bight Group (O'Brien *et al.* 1997).

Based on geochemistry and inherited zircon provenance, the lower magmatic sequence (i.e., middle-late Cambrian) in the Wild Bight and Exploits Groups have been interpreted as an oceanic magmatic arc (Penobscot Arc of van Staal *et al.* 1998) that formed on the Gondwana side of the Iapetus Ocean. These units serve as the basement of the younger volcano-sedimentary sequences. The younger Ordovician sequence in the Wild Bight, Exploits and Summerford Groups, and other units to the south, is deemed the Victoria Arc and is interpreted to have been built on the remains of the Penobscot Arc (van Staal *et al.* 1998). The two sequences are separated by a ca. 15 Ma magmatic hiatus spanning ~485-470 Ma (Fig. 4), which is interpreted as representing the time of closure of a backarc basin behind the Penobscot Arc (e.g. Williams and Piasecki 1990; van Staal *et al.* 1998). As the Victoria Arc was built on a basement recording an earlier orogenic event (Fig. 2), the structural unit made up of the Penobscot and Victoria Arc lithologies qualifies as a CPS (Fig. 4a, referred to as Penobscot and Victoria CPS).

Victoria Lake Supergroup in central Newfoundland (CPS). The Victoria Lake Supergroup occurs about 60 km south of the Wild Bight and Exploit Groups, to the east of the Beothuk Lake Line and structurally below rocks of the Annieopsquotch Tract (Evans and Kean 2002, Zagorevski *et al.* 2010) (Fig. 3; Fig. 4). It is made up of several fault-bounded units occupying a total width of ~50 km. The faults are interpreted as thrusts of post-Late Ordovician age (e.g., Zagorevski *et al.* 2007). These units have similar characteristics and are therefore grouped together in a singular sequence in Fig. 4b.

At the bottom of the Victoria Lake Supergroup is a ~5-km wide continental-affinity Neoproterozoic unit (Sandy Brook Group; Fig. 3; Fig. 4b) that lies structurally below the easternmost fault-bounded unit of the Victoria Lake Supergroup (McNicoll *et al.* 2008). The stratigraphy of the Sandy Brook Group is not well defined, but it is made up of volcanic rocks (basalts, mafic tuffs, andesite, cherty rhyolite; U-Pb zircon age of 563 ± 2 Ma; Rogers *et al.* 2006) associated with minor siliciclastic sedimentary rocks (Rogers *et al.* 2006) and intruded by several magmatic bodies (Crippleback Intrusive Suite) ranging in composition from pyroxenite, gabbro to diorite, quartz-monzonite (563 ± 2 Ma U-Pb zircon age; Evans *et al.* 1990), monzonite (565 +4/-3 Ma U-Pb zircon age; Evans *et al.* 1990) and granite (Evans and Kean 2002, Rogers *et al.* 2006). Geochemical analyses indicate an arc signature for both the felsic and mafic rocks of the Sandy Brook Group (Rogers *et al.* 2006). U-Pb dating of monazite in a quartz-monzonite yielded an age of 545 ± 3 Ma, which is interpreted as a metamorphic age (Evans *et al.* 1990). Although the contact with units of the Victoria Lake Supergroup to the west is faulted, such units contain inherited zircon with identical ages to the Sandy Brook Group, which is thus interpreted as the basement on which the Victoria Lake Supergroup was built (McNicoll *et al.* 2008; Rogers *et al.* 2006).

The fault-bounded units west of the Sandy Brook Group are made up of bimodal volcano-sedimentary sequences (i.e., Long Lake, Pats Pond, Tally Pond and Tulks Groups). Lithologies in these sequences comprise felsic tuff, tuff and volcanic breccia (487 ± 3 Ma U-Pb zircon age; Zagorevski *et al.* 2007), ash tuff, subvolcanic intrusions (491 ± 3 Ma U-Pb zircon age; Hinchey and McNicoll 2009), rhyolite (498 +6/-4 Ma U-Pb zircon age; Evans *et al.* 1990), pillow basalt, diabase, andesite, dacite (514 ± 7 Ma U-Pb zircon age; McNicoll *et al.* 2008), mafic-derived sedimentary rocks, volcaniclastic rocks (U-Pb zircon age of 506 ± 3 Ma; Zagorevski *et al.* 2010) and minor breccia (Zagorevski *et al.* 2010). Magmatic rocks in these units reveal an island arc signature (Rogers *et al.* 2006; Zagorevski *et al.* 2010), with juvenile island-arc tholeiite to, in some cases, calc-alkaline geochemistry (Zagorevski *et al.* 2010). Because of similar geochemical characteristics and ages, this bimodal sequence of ca. 514-486 Ma age is considered to represent Penobscot Arc lithologies and thus equivalent to the Wild Bight Group in northern Newfoundland (Zagorevski *et al.* 2010).

The Penobscot Arc is unconformably (McNicoll *et al.* 2008; Zagorevski *et al.* 2007, 2008) overlain by younger volcano-sedimentary sequences (i.e., Noel Paul's Brook, Sutherland Pond and Wigwam Brook groups) comprising felsic (U-Pb zircon ages ranging between 457-453 Ma; Zagorevski *et al.* 2007, 2008) and mafic tuff, rhyolite (462 +4/-2 Ma; Dunning *et al.* 1987a), felsic dykes, gabbro sills, basalt flows, epiclastic volcanic rocks, volcanogenic greywacke, siltstone and shale, breccia and conglomerate (McNicoll *et al.* 2008; Zagorevski *et al.* 2007, 2008). Furthermore, U-Pb zircon analyses from an orthogneiss unit in southern Newfoundland (Margaree orthogneiss) yield crystallization ages of 474 +14/-5 and 472 ± 3 Ma (Valverde-Vaquero *et al.* 2000). Volcanic and epiclastic components decrease towards the top and are overlain by black shale with minor volcanogenic siltstone and sandstone (McNicoll *et al.* 2008; Zagorevski *et al.* 2007, 2008). The magmatic rocks have within-plate trending to continental arc signatures (Zagorevski *et al.* 2007), and mafic rocks are E-MORB (Evans and Kean, 2002; Zagorevski *et al.* 2010). This led Zagorevski *et al.* (2007) to interpret these units as a continental arc and back-arc basin. These younger (i.e., 474-453 Ma) sequences are interpreted as part of the Victoria Arc (Zagorevski *et al.* 2010), separated from the older Penobscot Arc units by a ca. 10 Ma magmatic hiatus. The Ordovician volcano-sedimentary sequences in the Wild Bight, Summerford and Exploits Groups in northern Newfoundland – yielding similar magmatic ages and geochemical characteristics – are thus correlated to the Ordovician Victoria Lake Supergroup units (e.g., O'Brien *et al.* 1997; Zagorevski *et al.* 2010). Similarly to the Penobscot and Victoria CPS in northern Newfoundland, the Victoria Arc units of southern Newfoundland are built on an older crystalline basement (i.e., the Sandy Brook Group and Penobscot Arc); thus, the 'Victoria Lake Supergroup' sequence also qualifies as a CPS (Fig. 4b, referred to as 'Victoria Lake CPS').

Both the Penobscot and Victoria CPS in northern Newfoundland and the Victoria Lake CPS in central Newfoundland are conformably overlain by a widespread black shale unit (e.g., Dark Hole, Lawrence Harbour, Rogers Cove and Shoal Arm formations, often simply referred to as Caradoc black shale) of Upper Ordovician age (Sandbian-early Katian, ca. 458-450 Ma, graptolite age; Currie 1995; Williams *et al.* 1993; Waldron *et al.* 2012). This shale unit differentiates the "exotic" units assigned to the Penobscot and Victoria arcs from the ones lying west of the Beothuk Lake Line which lack a conformable marine cover (van Staal *et al.* 1998; Zagorevski *et al.* 2007; Waldron *et al.* 2012). The Caradoc black shale marks the magmatism cessation of the Victoria Arc (Zagorevski *et al.* 2007). It is gradually overlain by a coarsening-upwards, Upper Ordovician-to-Llandovery marine siliciclastic sedimentary sequence (Badger Group; Fig. 4). The Badger Group comprises greywackes grading into conglomerates and greywackes at its base, with olistostromal deposits and minor siltstones reported towards the top of the Group despite its general coarsening-upward character (Arnott 1983; Williams *et al.* 1993; Waldron *et al.* 2012). Zircon U-Pb analyses at the bottom and top of the Badger Group indicate sediment derivation from the Laurentian margin, so it is interpreted as a foreland basin succession deposited upon arrival of the underlying sequences at the margin of Laurentia (McNicoll *et al.* 2001; Waldron *et al.* 2012; Zagorevski *et al.* 2007 and references therein). The Badger Group exhibits folding that is not recorded in overlying Wenlock structures (Waldron *et al.* 2012), which is the structural signature of accretion in the early Silurian (Waldron *et al.* 2018). The Badger Group is unconformably (e.g., van Staal *et al.* 2014 and references therein) or paraconformably (e.g., Williams 1991, 1993) overlain by a widespread mid-late Silurian subaerial volcano-sedimentary succession (Botwood Group; Williams *et al.* 1993) comprising subaerial basalt flows, volcaniclastic rocks, felsic volcanic rocks (421 ± 4 and 419 ± 4 Ma U-Pb zircon ages) and red sandstone (Pollock *et al.* 2007; van Staal *et al.* 2014). The Botwood Group was regionally deformed before being intruded by gabbroic and granitic plutons of the Mount Peyton Intrusive Suite at ca. 424 Ma, i.e., in the mid-late Silurian (McNicoll *et al.* 2006). The Botwood Group is a facies equivalent of the Silurian volcano-sedimentary Springdale Group which unconformably overlies the Notre Dame Arc and Annieopsquotch Tract west of the Beothuk Lake Line, as they both contain facies attributed to the Old Red Sandstone of the British Caledonides (Chandler *et al.* 1987; Williams *et al.* 1993; van Staal *et al.* 2014) (Fig. 4a, b).

Ganderia Continental Margin: Meelpaeg CPS; Mount Cormack CPS; Ganderia CPS; Avalonia margin CPS And Hermitage Flexure

Several metamorphic continental units occur east of the Victoria Lake CPS that are interpreted as the microcontinent Ganderia (e.g., van der Velden *et al.* 2004; van Staal and Barr 2012; van Staal *et al.* 1998, 2021a). The metamorphic units are locally structurally overlain by ophiolitic units, and both are overlain by an unmetamorphosed cover sequence (Fig. 4).

Crystalline Basement: Hermitage Flexure. The crystalline basement of the metamorphosed continental units contains lithologies present in a restricted area of southwestern Newfoundland named the Hermitage Flexure, which comprises several Neoproterozoic tectonic windows making up an E-W trending belt (Dunning *et al.* 1990; Valverde-Vaquero *et al.* 2006b) (Fig. 3). This Hermitage Flexure is made up of ortho- and paragneiss (675 +12/-11 Ma; Valverde-Vaquero *et al.* 2006b), low-grade Ediacaran volcano-sedimentary rocks and felsic and mafic intrusive rocks (e.g., Roti Intrusive

Suite) with 578 ± 10 to 495 ± 2 Ma (U-Pb ages of granodiorites and gabbro; Dunning and O'Brien 1989; O'Brien *et al.* 1991; Dubé *et al.* 1995). These intrusions are cross-cut by oblique-convergent deformation (O'Brien *et al.* 1993). Contacts between the Hermitage Flexure and surrounding lithologies are mostly obscured by younger intrusions (Conliffe *et al.* 2024) (Fig. 3). This region exhibits a similar Neoproterozoic geological history to Avalonia, but has more recently been interpreted as the basement of the microcontinent Ganderia, based on reflection seismic studies, the difference in metamorphism with the basement of Avalonia, and correlations with other Ganderian terranes in mainland Canada (e.g., Valverde-Vaquero *et al.* 2006b; van der Velden *et al.* 2004; van Staal *et al.* 2021a; Waldron *et al.* 2022). Hermitage Flexure lithologies are correlated with the Sandy Brook Group at the base of the Victoria Lake CPS (Rogers *et al.* 2006) (Fig. 3; Fig. 4b) described in the previous section.

Ganderia Continental Units (CPS). The most complete sequence of metamorphosed continental units is a ~60-km wide belt of deformed metasedimentary and igneous rocks in the east (Fig. 3). The metasedimentary units belong to the Gander Group, which comprises quartz-rich sandstones, siltstones and shales now metamorphosed to psammitic and pelitic schists of middle-upper greenschist facies, with minor mafic dykes and greenschist horizons that were originally tuffs (Bazinet 1980; Currie 1995; Nance *et al.* 2008). No fossils were identified in this unit, but its maximum age is inferred at 545 Ma based on the age of a detrital titanite in the bottom part of the section (van Staal *et al.* 1996 and references therein). It is older than 474 Ma based on cross cutting relationships with intrusive granites (van Staal *et al.* 1996 and references therein). Deformation structures are different compared to the overlying units that contain Middle-Late Ordovician fossils, which indicates that the minimum age of the Gander Group must be Lower Ordovician (Bazinet 1980). Metamorphic conditions are not well-quantified but are roughly greenschist facies (Bazinet 1980). The metamorphic grade of the Gander Group increases to the east, reaching amphibolite conditions in pelitic gneisses of the Square Pond Gneiss (Blackwood 1977; O'Neill 1992). The Gander Group is interpreted as deposition at a continental margin on the eastern (present coordinates) side of the Iapetus Ocean (Bazinet 1980; van Staal *et al.* 2014, 2021a). Clastic syn-rift sequences are capped by pelagic sediments representing a deeper marine environment and the end of rifting (van Staal *et al.* 2021a). Detrital zircons indicate that the sediment source was continental Gondwana and, more specifically, a possible derivation from Amazonia, similarly to correlated Ganderian units in New Brunswick and Maine (Currie 1995 and references therein; Willner *et al.* 2014 and references therein). East of the Gander Group, a band of gneissic units (Hare Bay Gneiss, Fig. 3) are interpreted as part of the same succession, since there is no evidence for deformation or unconformities (Holdsworth 1994). The Hare Bay Gneiss comprises upper amphibolite-facies metasediments (paragneiss and migmatites) interpreted as high-grade equivalents of the Gander Group; greenschist-facies orthogneiss with granitic to tonalitic composition; and amphibolites interpreted as metamorphosed mafic intrusions (Blackwood 1977; D'Lemos *et al.* 1997; Holdsworth 1994; Langille 2012). The orthogneisses yield 510 ± 4 and 491 ± 4 Ma U-Pb zircon ages (Langille 2012) but lack any geochemical study. The Hare Bay Gneiss is intruded by several granitic bodies that are lithologically indistinguishable from the Cambrian orthogneiss (Holdsworth 1994). Apart from two Middle Ordovician ages (465 ± 2 and 460 ± 2 Ma U-Pb zircon ages of a granitic orthogneiss and leucogranite, respectively), intrusions in this area yield Wenlock (428-412 U-Pb zircon ages of leucogranites, tonalites, granites) to Middle Devonian ages (387 ± 2 Ma U-Pb zircon age of a late

pegmatite) (Langille 2012). The granites are foliated and thus interpreted as deformed during formation of the Wing Pond shear zone (see below) (Holdsworth 1994; D'Lemos *et al.* 1997). Orthogneisses and later intrusions show similar geochemical signatures that suggest melting of sedimentary crustal material (Langille 2012). The Gander Group and Hare Bay Gneiss present features of Continental Plate Stratigraphy and we thus interpret this nappe as a CPS (Fig. 4, referred to as Ganderia CPS).
The Gander Group and Hare Bay Gneiss are bounded to the east by the steeply dipping Dover-Hermitage Bay Fault (Fig. 3), a dextral ductile shear zone that overprints the wider, sinistral Wing Pond shear zone (Langille 2012; Kellet *et al.* 2016). Seismic imaging indicates this fault-and-shear is a crustal-scale structure that offsets the Moho and separates crustal terranes with different seismic characteristics (Keen *et al.* 1986). The Wing Pond Shear Zone operated in the late Silurian to Devonian (between 422-394 Ma), based on U-Pb dating on monazite and $^{40}Ar/^{39}Ar$ dating on white mica in granites close to the Dover Fault (Kellett *et al.* 2016). The younger Dover Fault was active in the middle to late Devonian, between ca. 385 Ma ($^{40}Ar/^{39}Ar$ on white mica; Kellet *et al.* 2016) and 377 ± 4 Ma (age of a granite stitching the fault; O'Brien 1998 reported in Lynch *et al.* 2009). Total displacement along this fault zone is not constrained.

Avalonia Margin (CPS). Due to the strike-slip nature of the Dover-Hermitage Bay Fault, the lithologies east of the Fault are offset compared to their original position in the Late Ordovician-early Silurian. However, their basement is different from the units to the west, and therefore they do not represent a repetition of the Ganderia units located to the west of the Fault. These units comprise the Avalon Zone (Williams 1979) or Avalonia. The Avalon Zone exhibits a Neoproterozoic basement with a complex tectonic history, comprising a variety of sedimentary and magmatic arc-related rocks ranging from ca. 760 to 545 Ma and interpreted to represent subduction below the Gondwana margin (O'Brien *et al.* 1996; Nance *et al.* 2002; van Staal *et al.* 2021b). The magmatic units display calk-alkaline and arc tholeiite bimodal geochemistry (O'Brien *et al.* 1996). The sedimentary rocks transition from marine to terrestrial in the latest Neoproterozoic (O'Brien *et al.* 1996). The Precambrian basement is unconformably overlain by quartz-arenites and conglomerates (Random Formation) passing to fine grained, deeper marine to near-shore mudstones and limestones of lower Cambrian (Terreneuvian-Series 2) fossil age that were assigned different names in the literature (e.g., Brigus, Foster Point formations and Bonavista and lower Adeyton Group; O'Brien *et al.* 1996; Landing 1996; O'Brien and King 2005; Fletchers 2006; Álvaro 2021). The lower Cambrian succession unconformably overlies the basement in locations where the terrestrial units are absent. The Neoproterozoic basement and Cambrian sedimentary sequence have been correlated to units in North Africa with Gondwanan affinity (O'Brien *et al.* 1983), similar to the sedimentary units of Ganderia and associated terranes to the west. The latest Precambrian to early Cambrian sequence is interpreted to record the evolution from subduction with a well-developed arc to platformal sedimentation without robust evidence for continental collision (O'Brien *et al.* 1996; Nance *et al.* 2002). The lower Cambrian marine sediments shift into middle-late Cambrian siliciclastic pelagic sediments, mudstones, shales and siltstones locally with basalts and sills (e.g., Chamberlain's Brook, Manuel's River formations and Harcourt Group; Landing 1996; O'Brien *et al.* 1996; Fletchers 2006; Pohlner *et al.* 2020). Tuffs intercalated with the mudstones yielded U-Pb zircon ages of ca. 508-506 Ma (Landing *et al.* 2023). The overlying Lower Ordovician units are extremely geographically restricted and record a gradation from shale to sandstone, siltstone and quartz arenite and then, in the upper part of the Lower Ordovician, to quartz-arenites, micaceous sandstones, siltstones and oolitic hematite (i.e., upper Bell Island Group and Wabana Group; O'Brien *et al.* 1996; Todd *et al.* 2019 and references therein). Fossil fauna in these marine sediments is interpreted as peri-Gondwanan (Fletchers *et al.* 2006). Cambrian to Lower Ordovician platformal sedimentation is attributed to intracontinental rifting or transtensional pull-apart basins (O'Brien *et al.* 1996); the Middle Cambrian bimodal volcanism is possibly consistent with intracontinental rifting (Nance *et al.* 2002). The Lower Ordovician coarser sediments have not been paleogeographically interpreted, but they might represent foreland basin deposits, deposited on top of shales of a passive margin. Younger geological records do not exist for this area of eastern Newfoundland, although seismic profiles and drilled cores offshore show that Ordovician-Silurian shales are overlain by post-orogenic Devonian redbeds (Holdsworth 1994 and references therein). Similarly to the Ganderia CPS, we interpret units to the east of the Dover-Hermitage Bay Fault as representing Continental Plate Stratigraphy (Avalonia CPS in Fig. 4).

Meelpaeg and Mt. Cormack (CPS). Several units correlative to the Ganderia CPS are preserved to the west and south of the Gander Group (i.e., Meelpaeg Metamorphic Nappe and Mount Cormack Terrane; Fig. 3).

The **Meelpaeg** Metamorphic Nappe, or Meelpaeg Metamorphic allochthon, is a ~40-km wide metamorphic continental unit (Fig. 3) bounded by shear zones with a sharp metamorphic transition from greenschist- to amphibolite-facies both in the west and east (van der Velden *et al.* 2004; Valverde-Vaquero and van Staal 2001; Valverde-Vaquero *et al.* 2006a). The western boundary is interpreted as an east-dipping thrust (Valverde-Vaquero and van Staal 2001) and the eastern boundary as an east-dipping, low angle normal fault (van der Velden *et al.* 2004 and references therein). The Meelpaeg Nappe is made up of metapsammites, semipelites, quartzites, orthogneiss and migmatitic gneiss interpreted as continental margin units of Ganderia (Valverde-Vaquero *et al.* 2006a). Early Devonian metamorphism (420-411 Ma monazite U-Pb age on metamorphic rocks and syn-metamorphic plutons) intensifies towards the core of the nappe (Valverde-Vaquero *et al.* 2006a and references therein). The Meelpaeg Nappe is interpreted to record deep burial followed by extrusion towards the NW in the early Devonian (van der Velden *et al.* 2004).

Along the western boundary of the nappe, a narrow (~3-km wide) belt of high-grade metamorphic volcano-sedimentary rocks called the Howley Waters Complex (Valverde-Vaquero and van Staal 2001) comprises pelite, psammite, and greywacke interlayered with minor felsic porphyries (467 ± 3 Ma U-Pb zircon age; Valverde-Vaquero *et al.* 2006a), calcsilicate, marble and amphibolite. The contact between the Howley Waters Complex in the west and the Meelpaeg Nappe to the east is a band of granite intrusives of ca. 467-468 Ma (U-Pb zircon age; Valverde-Vaquero *et al.* 2006a). These intrusions appear to stitch the original contact between the nappes and provide a minimum age for deposition of the Howley Waters Complex protoliths (Valverde-Vaquero *et al.* 2006a). Due to lithological similarities and the Ordovician age of the porphyry, the Howley Waters Complex is correlated with units of the widespread cover sequence (Ganderia Overstep Sequence, see detailed description below) which overlies Cambrian continental and ophiolitic units (Valverde-Vaquero *et al.* 2006a; Fig. 4). This cover sequence is unmetamorphosed, whereas the Howley Waters Complex shows high-grade metamorphism. Metamorphic ages of this complex have not been determined but could be related to the Devonian metamorphism recorded in the underlying Meelpaeg Nappe, i.e., Devonian in age (Valverde-Vaquero *et al.* 2006a).

In southern Newfoundland, correlatives of the Meelpaeg Nappe and Howley Waters Complex are represented by the **Port-aux-Basques** and Grand Bay complexes, respectively (Williams *et al.* 1988; van Staal *et al.* 1996; Valverde-Vaquero *et al.* 2006a) (Fig. 3), which are part of the Meelpaeg structure as defined by van Staal *et al.* (2024). The Port-aux-Basques Complex is a ~10 km wide unit comprising metasandstones, paragneiss and schists which are interpreted as high-grade equivalents of the Gander Group to the northeast (Valverde-Vaquero *et al.* 2006a; van Staal *et al.* 2021, 2024). No biostratigraphic ages are available for this complex, but it is intruded by Early-Middle Ordovician orthogneisses (ca. 474-465 Ma U-Pb zircon ages; Valverde-vaquero *et al.* 2000; van Staal *et al.* 2024). The Grand Bay Complex is located immediately to the west of the Port-aux-Basques Complex, from which it is separated by a Lower Devonian southeast dipping dextral-oblique reverse fault (van Staal *et al.* 2024). The Gran Bay Complex is made up of schists, orthogneisses and mafic amphibolites interpreted to have deposited above the Port-aux-Basques Complex in the Lower-Middle Ordovician, based on structural relationships and on the ages of stitching plutons (van Staal *et al.* 2024). Similarly to the Meelpaeg Nappe farther north, metamorphism of the Port-aux-Basques and Grand Bay Complexes is Early Devonian (ca. 418-403 U-Pb monazite and titanite and $^{40}Ar/^{39}Ar$ hornblende and muscovite ages; Dunning *et al.* 1990; Dubé *et al.* 1996; Valverde-Vaquero *et al.* 2000; van Staal *et al.* 2024 and references therein) and increases in grade from the northwest (i.e., the Grand Bay Complex) to the southeast (i.e., the Port-aux-Basques Complex), from staurolite to sillimanite zone (Burgess *et al.* 1995; van Staal *et al.* 2024).

To the east of the Meelpaeg Nappe in central Newfoundland, metasedimentary rocks called the Spruce Brook formation occupy the **Mount Cormack** Terrane (Fig. 3). Structural relationships are unknown, because they lie below the younger Ganderia Overstep Sequence (see below). The Mount Cormack Terrane makes up a concentric metamorphic zone with greenschist-facies conditions at the edge to migmatite-facies towards the core, with paragneiss, migmatite, tonalite, and amphibolite (Jenner and Swinden 1993; Valverde-Vaquero *et al.* 2006a). In areas with low-grade metamorphism, the original composition of the Spruce Brook Formation is described as light grey quartz-rich sandstone and grey and black shales with laminae and intercalations of siltstone and fine-grained sandstone (Colman-Sadd and Swinden 1984). The formation has not been dated, but correlations with other formations in eastern Newfoundland and New Brunswick suggest a minimum Lower Ordovician depositional age (Dec and Colman-Sadd 1990; van Staal *et al.* 2021a). U-Pb dating of monazite and titanite in migmatite and amphibolite yielded metamorphic ages of ca. 462-460 Ma (Valverde-Vaquero *et al.* 2006a), consistent with zircon and monazite dating of a migmatitic gneiss (465 ± 2 Ma; Colman-Sadd *et al.* 1992a, reported in Valverde-Vaquero *et al.* 2006a), thus constraining metamorphism to the Middle Ordovician. Colman-Sadd and Swinden (1984) interpreted the Spruce Brook formation as a tectonic window into the Ganderia basement, because of its lithological correlations with sedimentary units (Gander Group) to the east. Rocks equivalent to the Mount Cormack Terrane are also thought to form the basement of the Red Cross Group (Fig. 3), which has been interpreted as part of the widespread overstep cover sequence (see detailed description below; Valverde-Vaquero *et al.* 2006a; van Staal *et al.* 2021a).

Due to their correlation with the Gander Group, we interpret both the Meelpaeg Nappe and the Mt. Cormack Terrane as CPS sequences (Meelpaeg CPS and Mt. Cormack CPS in Fig. 4b).

Ophiolites: Pipestone Pond; Coy Pond; Gander River

Ophiolite slivers structurally overlie the continental units described above. They are interpreted as remnants of an oceanic basin that formed behind the Penobscot Arc and that was thrust eastwards over the Gander Group and correlative Meelpaeg Nappe and Mount Cormack Terrane (Fig. 4) (Colman-Sadd and Swinden 1984; Colman-Sadd *et al.* 1992; Jenner and Swinden 1993; Zagorevski *et al.* 2010; Sandeman *et al.* 2012). Early Ordovician metamorphism of these nappes – except for the Meelpaeg Nappe which records Devonian metamorphism (see above) – may therefore record their burial beneath the ophiolites.

To the east of the Meelpaeg Nappe in central Newfoundland is the ~5-km wide **Pipestone Pond** Complex (Fig. 3), which is separated by a poorly defined contact interpreted as a fault (Colman-Sadd and Swinden 1984). The Pipestone Pond Complex structurally overlies the Spruce Brook Formation of the Mount Cormack Terrane to the east (Colman-Sadd and Swinden 1984). The complex consists of a disrupted sequence comprising harzburgite, cumulate pyroxenite, layered and massive gabbro intruded by pegmatitic gabbro, diabase dykes, plagiogranite (494 ± 2.5 Ma U-Pb zircon age; Dunning and Krogh 1985) and pillow lava (Jenner and Swinden 1993). Gabbro geochemistry indicates a suprasubduction zone setting; diabase and plagiogranite exhibit island arc tholeiite affinity; and the basalts have a MORB affinity (Jenner and Swinden 1993).

To the east of the Mount Cormack Terrane lies the ~5-km wide **Coy Pond** Ophiolite (Fig. 3) (Sandeman *et al.* 2012). This unit contains harzburgite, pyroxenite, mafic dykes, plagiogranite (510 ± 4 Ma U-Pb zircon age; Sandeman *et al.* 2012), as well as diabase, gabbro and mafic pillow lavas, which are conformably overlain by argillite, sandstone and polymictic conglomerate (Zagorevski *et al.* 2010; Sandeman *et al.* 2012). Geochemical analyses on this complex are scarce, but basalts exhibit tholeiitic affinity, and felsic rocks have primitive arc affinity (Zagorevski *et al.* 2010). The Coy Pond complex is stitched to the Mount Cormack Terrane by a granitic intrusion dated at 474 +6/-3 Ma (U-Pb zircon age; Colman-Sadd *et al.* 1992), which constrains obduction of the ophiolites over continental rocks of the Ganderia continental margin to the Lower Ordovician.

The **Gander River** Ultramafic Complex, or Gander River Complex (Currie 1995; Williams 1995) occupies a ~5-km wide, NNE-SSW band in northern-central Newfoundland (Fig. 3), and structurally overlies metasediments of the Gander Group to the east (Bazinet, 1980; O'Neill, 1990 and references therein). The Gander River Complex is a deformed sequence of dominantly ultramafic rocks (pyroxenite, serpentinite), gabbro, diorite, and minor plagiogranites and mafic volcanic rocks (Bazinet 1980; O'Neill and Blackwood 1989; O'Neill 1990). Studies on this complex are scarce and it has not been dated, but geochemical analyses by O'Neill (1991) showed that mafic rocks have an island arc tholeiitic signature. Based on its structural position it has been correlated with the Pipestone Pond and Coy Pond Complexes farther to the west (Colman-Sadd and Swinden 1984; Jenner and Swinden 1993).

Ganderia Overstep Sequence

The units interpreted as the Ganderia continental margin and overlying ophiolites are structurally, unconformably or conformably overlain by several volcanic and (volcano-)sedimentary sequences spanning the Middle Ordovician-late Silurian (Bazinet 1980; Williams *et al.* 1993; Currie 1995; Valverde-Vaquero *et al.* 2006a; van Staal *et al.* 2014; Westhues and Hamilton 2018). In the following, we first describe restricted volcanic units of oceanic affinity mainly exposed in northern Newfoundland, and we then describe the more widespread sedimentary units exposed to the east of the volcanics. We group all units in the Ganderia Overstep Sequence (after Valverde-Vaquero *et al.* 2006a).

Oceanic units. In northern Newfoundland, dark shales, siltstone, conglomerate and minor volcanic rocks (felsic tuffs of 469 ± 2 Ma U-Pb zircon age, pillow lavas) east of the Badger Group are part of the **Duder Complex** (previously Duder Group, Williams *et al.* 1993; Currie 1997; Dickson 2006; Zagorevski *et al.* 2010) (Fig. 3). The Duder Complex is faulted on all sides, thus its original relationships with the surrounding and older units are unclear (Williams *et al.* 1993; Currie 1997; Dickson 2006; van Staal *et al.* 2014). The complex is intruded by gabbro dykes yielding 453 ± 1.3 Ma U-Pb baddeleyite age, interpreted as its minimum age (McNicoll *et al.* 2006, reported in Dickson *et al.* 2007). On its eastern side, the lithologies of the Duder Complex are found in a mélange (Garden Point Mélange), comprising mafic volcanic rocks and gabbros in disrupted black shale (Williams *et al.* 1993). No geochemical data is available on these units. Attribution and interpretation of this Complex is unclear: it has been interpreted as the remains of an accretionary complex testifying to subduction of an oceanic basin between units of the Victoria Arc and a trailing edge of Ganderia (e.g., Williams *et al.* 1993, van Staal *et al.* 2014). However, some authors (e.g., Dickson 2006, Dickson *et al.* 2007) consider this unit as related to the Badger Group (i.e., the siliciclastic sequence overlying the Victoria Arc units, see above).

The eastern boundary the Duder Complex, where the Garden Point Mélange is exposed, is represented by the Dog Bay Line (Williams *et al.* 1993, Fig. 3). The Dog Bay Line is a high-strain zone with dextral and transpressive displacements and is defined as separating siliciclastic and subaerial volcanic units of the Badger and Botwood Groups in the west (i.e., foreland basin units overlying the Victoria Arc, and their volcano-sedimentary cover sequences, respectively; see 'Penobscot and Victoria CPS units' section), and units of the Ganderia Overstep Sequence in the east (Williams *et al.* 1993; Pollock *et al.* 2007). The Dog Bay Line was defined based on contrasts in the stratigraphy and level of deformation on either side (Williams *et al.* 1993; McNicoll *et al.* 2006; van Staal and Barr 2012), and, due to the presence of oceanic volcanic units of the Duder Complex, is speculated to represent a suture along which a back-arc basin, located behind the Victoria Arc, was subducted (e.g., Currie, 1995; Valverde-Vaquero *et al.* 2006a; Williams *et al.* 1993).

To the east of the Duder Complex and Dog Bay Line, volcanic units of oceanic affinity are found in the **Hamilton Sound Group** (Fig. 3). The Hamilton Sound Group, a few km in width, comprises volcaniclastic conglomerate and sandstone, basaltic lavas, mafic dykes, bedded tuff, lapilli breccia, overlain by siltstones, shale and sandstones (Johnston *et al.* 1994, Currie 1997). The internal stratigraphy of the complex is not well defined, but the sedimentary lithologies are inferred to overlie the volcanic rocks (Johnston *et al.* 1994, Currie 1997). Middle Ordovician fossils in the shales provide the only available ages for the Hamilton Sound Group, which is in general considered to be Middle-Upper Ordovician (Currie 1997; Dickson 2006 and references therein). The basalts of the Hamilton Sound Group have tholeiitic affinity, with N-MORB and E-MORB geochemical signature (Johnston *et al.* 1994). The lithologies of the Hamilton Sound Group are also found as a mélange (Carmanville Mélange), which also contains ultramafic blocks inferred to derive from the Gander River Ultramafic Complex (refer to description in the previous section; Lee 1994; Jonhston *et al.* 1994; Currie 1997). The age of the Carmanville Mélange is inferred to be Upper Ordovician or younger as its matrix is made up of shale similar to the widespread 'Caradoc shale' overlying the Victoria Arc (Currie 1997).

Oceanic units are less exposed east of the Victoria Arc in central and southern Newfoundland, thus the southern continuation of the Dog Bay Line is not well defined.

The **Pine Falls Formation**, to the east of the Victoria Arc units in central Newfoundland (Fig. 3) is considered one of such oceanic units and has been correlated to the Duder Complex and to the Hamilton Sound Group (Valverde-Vaquero *et al.* 2006a; van Staal *et al.* 2014). It is part of the volcano-sedimentary Red Cross Group, which we include in the (volcano-) sedimentary units of the Ganderia Overstep Sequence (see detailed description below). However, the Pine Falls Formation does not have any stratigraphic relationships with the rest of the Group, as its original contacts are sheared (Valverde-Vaquero *et al.* 2006a). The Pine Falls Formation comprises pillow basalts, interlayered with limestones and shales; its age is inferred to be Upper Ordovician due to the lithological similarity between the shale and the widespread 'Caradoc shale', and between the limestone lenses and similar limestones which have yielded Middle-Upper Ordovician fossil ages (Valverde-Vaquero *et al.* 2006a and references therein). The basalts in the Pine Falls Formation have tholeiitic affinity, with geochemical signature ranging between N-MORB and island arc tholeiite and are interpreted to have formed in a back-arc basin (Valverde-Vaquero *et al.* 2006a).

All the oceanic units described above are interpreted to represent the remains of a (back-arc) basin that separated the Victoria Arc CPS units from a 'trailing edge' of Ganderia, of which the Dog Bay Line is considered the suture, as previously mentioned (e.g., Williams *et al.* 1993, Valverde-Vaquero *et al.* 2006a; van Staal *et al.* 2014).

(Volcano-) sedimentary units. The volcano-sedimentary units form the Ganderia Overstep Sequence (*sensu stricto*), which comprises volcaniclastic, sedimentary and minor volcanic sequences that are interpreted to have been deposited above the units of the Gander margin or on the ophiolites. The Ganderia continental margin units and the ophiolites represent an earlier orogenic event and thus served as the 'basement' upon which the Ganderia Overstep Sequence sedimentary units were deposited. Therefore, we consider the overstep to be a CPS sequence. The westward extent of the Ganderia Overstep Sequence is in tectonic contact with the Victoria Lake CPS or with the oceanic units described above, along the Dog Bay Line (or its inferred southern continuation) (Fig. 3). Initial deposition of the Ganderia Overstep Sequence was contemporaneous with metamorphism of the Mount Cormack Terrane in the Middle Ordovician and local plutonic magmatism; since the latter processes are attributed to metamorphic core complexes and rifting (Valverde-Vaquero *et al.* 2006a and references therein), deposition of the Ganderia Overstep Sequence might be the upper crustal or superficial record of regional rifting.

East of the Dog Bay Line in northern Newfoundland, the sedimentary rocks of the Ganderia Overstep Sequence comprise a local unit of Caradoc black shale overlain by Middle-Late Ordovician (fossil ages; Currie 1995 and references therein) limestone, shale, turbiditic sandstone, and debris flow conglomerates of the **Davidsville Group** (Pollock *et al.* 2007). Clasts in the conglomerates of the Davidsville Group are derived from ophiolitic rocks of Ganderia (Pollock *et al.* 2007). The Davidsville Group is conformably (McNicoll *et al.* 2006) or unconformably (Currie 1995) overlain by a succession of shale and limestone passing upwards to subaerial redbeds (Indian Islands Group; Boyce *et al.* 1993; Williams *et al.* 1993; McNicoll *et al.* 2006; Pollock *et al.* 2007) of Llandovery to uppermost Silurian-Lower Devonian age (fossil ages; Pollock *et al.* 2007 and references therein). The Indian Islands Group also unconformably overlies the Hamilton Sound Group (see description above) (Johnston *et al.* 1994 and references therein). The bulk of the Indian Islands Group has Wenlock-

Ludlow ages (McNicoll *et al.* 2006), and the timing of change from marine to subaerial sedimentation is not well defined. Some authors report that, although the Indian Islands Group is exposed east of the Dog Bay Line, few units on the west of the Line contain clasts that can be attributed to this group (e.g., Currie 1997; Dickson 2006). The Indian Islands Group exhibits deformation through slaty cleavage which formed before intrusion of gabbro dykes of ca. 411 Ma, therefore constraining a minimum deformation age to the early Devonian (McNicoll *et al.* 2006). This contrasts with units of the Botwood Group which lie west of the Dog Bay Line and were deformed in mid-late Silurian, indicating different deformation histories (e.g., Honsberger *et al.* 2023). Therefore, the Middle-Late Ordovician Davidsville Group (and correlatives, see below) predates the arrival of Ganderia at the Laurentian margin as marked by the Badger Group (Fig 4). In contrast, the early Silurian-Early Devonian Indian Islands Group in northern Newfoundland post-date it and is thus post-orogenic with respect to the accretion of the Victoria Arc to Laurentia.

The Davidsville Group has been correlated to other sedimentary units in central and southern Newfoundland (i.e., Red Cross Group, Baie d'Espoir Group, Bay du Nord Group; van Staal *et al.* 2021a; Waldron *et al.* 2022).

On its western side in central Newfoundland, the Overstep Sequence is a ~10-km wide volcano-sedimentary composite unit named the **Red Cross Group** (Fig. 3) that is emplaced via a Devonian NW-directed thrust over the Victoria Lake Supergroup (Valverde-Vaquero *et al.* 2006a, b). The Red Cross Group comprises volcanic tuff, tuffaceous sandstone, siltstone, felsic porphyry (466 ± 3 Ma U-Pb zircon age), rhyolite and basalt with E-MORB and minor calc-alkaline geochemistry (Valverde-Vaquero *et al.* 2006a), and its northwestern contact is a reverse fault which juxtaposes the Pine Falls Formation (described above) above the Group (Valverde-Vaquero *et al.* 2006a). A gabbro intruding volcano-sedimentary rocks of the Red Cross Group and dated 457 ± 6 Ma (U-Pb zircon age; Valverde-Vaquero *et al.* 2006a) constrains the minimum age for the group. The magmatic arc signature may indicate proximity to the Victoria Lake CPS (Fig. 3). Valverde-Vaquero *et al.* (2006a) interpret volcanism in the Red Cross Group as opening of a back-arc basin behind the Victoria Arc, based on the intermediate signature of the volcanic lithologies between MORB and island arc (including the ones of the Pine Falls Formation) and correlations with bimodal geochemistry in Ordovician volcanic rocks of the Wild Bight Group (refer to the 'Penobscot and Victoria CPS units').

The **Baie d'Espoir** Group, in southeastern Newfoundland (Fig. 3), has not been well described due to poor exposure and isoclinal folding which precludes thickness evaluation (Sandeman *et al.* 2012). It comprises felsic volcanic flows (of which a rhyolitic tuff yielded 465.7 ± 0.5 Ma U-Pb zircon age) with minor mafic and intermediate volcanic rocks, tuffs, polymictic conglomerate, and volcaniclastic sandstones and clastic sedimentary rocks (Sandeman *et al.* 2012; Westhues and Hamilton 2018). Geochemical analyses indicate that the volcanic rocks are sub-alkaline, and mafic rocks exhibit volcanic arc calc-alkaline to transitional signatures (Westhues and Hamilton 2018). These signatures support correlations between the Red Cross Group and justify interpreting the Baie d'Espoir magmatism as rifting of a backarc basin (Valverde-Vaquero *et al.* 2006a).

Like the Baie d'Espoir Group, the **Bay du Nord Group** of southern Newfoundland (Fig. 3) is a composite group comprising volcano-sedimentary rocks that were metamorphosed to upper greenschist and amphibolite facies (Tucker *et al.* 1994). This group is bounded by Silurian intrusions and by a Silurian strike-slip fault zone in the north (Lin *et al.* 1994) and Silurian south-dipping reverse fault in the south (O'Brien and O'Brien 1990; Tucker *et al.* 1994) (Fig. 3). The original relationships of the Bay du Nord group with the surrounding lithologies are therefore unclear. This group comprises felsic volcano-sedimentary rocks, felsic tuff (466 ± 2 Ma; Dunning *et al.* 1990), minor psammite, pelite, and conglomerate (Tucker *et al.* 1994) and has been correlated with the Davidsville Group (e.g., Colman-Sadd 1980; Colman-Sadd and Swinden 1982; van Staal *et al.* 2021a). Metagabbro is locally imbricated with these lithologies and is interpreted as the basement of the Bay du Nord Group; it may have been a backarc basin to the Penobscot Arc which closed by the Early Ordovician (Tucker *et al.* 1994; van Staal *et al.* 2021a). In contrast to unmetamorphosed units of the Ganderia Overstep Sequence, the Bay du Nord Group is metamorphosed, likely during the Devonian (Dunning *et al.* 1990; van Staal *et al.* 2024). This event would be coeval with thrusting of the Red Cross Group and Meelpaeg Nappe to the west (Valverde-Vaquero *et al.* 2006a) (see 'Ganderia continental margin' section) and thus post-dates the accretion of Ganderia to the Laurentian margin.

The tectonic units of the Ganderian continental margin (i.e., Meelpaeg Nappe, Hermitage Flexure, Ganderian continental margin CPS, Avalonia CPS), the ophiolites structurally above them (i.e., Coy Pond, Gander River, Pipestone Pond) and the Ganderia Overstep Sequence are intruded by a series of felsic plutons with ages ranging from the Silurian to the Late Devonian (e.g., Dunning *et al.* 1990; Elliott *et al.* 1991; O'Brien *et al.* 1991; Kerr *et al.* 1993; Kerr 1997; van Staal and Barr 2012; Graham *et al.* 2021; Wang *et al.* 2024). These intrusions range in age from ca. 435 to ca. 378 Ma and show a younging migration towards E, with the Silurian-Early Devonian ones intruding units west of the Dover-Hermitage Bay Fault and the youngest, Middle to Late Devonian ones intruding the Avalonian units east of the Dover Fault and the fault itself (Wang *et al.* 2024 and reference therein). Their geochemistry varies with their age, with the oldest Silurian-Early Devonian plutons yielding subduction-related arc signature interpreted as reflecting ongoing westward subduction and younger Middle-Late Devonian plutons yielding within-plate signature typical of post-orogenic magmatism (e.g., Wang *et al.* 2024).

INTERPRETATION OF OROGENIC ARCHITECTURE DIAGRAMS

Our orogenic architecture diagrams display summaries of the compiled data, including interpretations of whether units are continental plate stratigraphy (CPS), oceanic plate stratigraphic (OPS), or continental or oceanic upper plate units (Figs. 4a, b). The Laurentian continental margin and Gondwana-derived units occupy the west-northwest and east-southeast sides of the orogen in present-day coordinates, respectively. They are illustrated on the left and right sides of the orogenic architecture diagrams (Figs. 4a, b). Below, we use these diagrams to develop a reconstruction of the paleogeographic and tectonic evolution that led to the orogeny in Newfoundland along a roughly west-east cross section (Fig. 5), bearing in mind that the northwestern and southeastern section may have been displaced over ~250 km after accretion (Waldron *et al.* 2015). Our model includes rifting and drifting phases and associated igneous and sedimentary processes, and subsequent convergence and stages of orogenesis. For this interpretation, we deliberately *only* refer to our diagrams, to evaluate the utility of the methodology proposed above. Note that many of our interpretations below are very similar to previous interpretations, which we will address in more detail in the Discussion section, where we compare our orogenic architecture interpretation with previously proposed models to evaluate strengths and limitations of our approach.

The Laurentian Margin Records a Full Wilson Cycle

The Laurentian continental margin records continental plate stratigraphy with a straightforward paleogeographic and tectonic history characterized by rifting of older continental lithosphere, passive margin sedimentation and seafloor spreading, followed by oceanic closure. A Grenvillian basement inherited from a previous orogenic cycle underlies the rift-and-drift-related (volcano-) stratigraphy. Continental break-up occurred between ca. 615 and 550 Ma (Fig. 5a), as indicated by rift volcanic rocks intercalated with syn-rift clastic sedimentary rocks.

A passive margin phase followed the onset of 'oceanization' (i.e., the drift phase), recorded by post-rift sedimentary rocks comprising limestones, mudstones and shales of late early Cambrian-Early Ordovician age atop the rift-related volcano-sedimentary sequence. Seafloor spreading occurred to the east (present coordinates) of the Laurentian margin (Fig. 5b), indicated by the grading of more proximal post-rift facies in the structurally lower, western nappes to more distal post-rift facies in the structurally higher, eastern nappes. All units contain detritus that indicate the sedimentary rocks were derived from material shedding off the Laurentian continental margin. The ocean east of Laurentia was subsequently consumed in an orogenic phase characterized by east-directed subduction and west-directed thrusting. This step is indicated by east-dipping flysch sequences that young structurally downward, indicating that foreland thrusts propagated in the continental units from east to west between ca. 470 to 460 Ma (Fig. 5e, f).

Following the sequence of events proposed so far, we hypothesize that to the east we will either find the eastern continuation of the lower plate, i.e., a CPS or OPS with older flysch, and older metamorphism (if burial was deep enough), or geological remnants of an overriding plate. Our diagram shows that the Coastal Complex and Bay of Islands ophiolite are east of the Laurentian CPS, therefore supporting the latter hypothesis.

The Coastal Complex currently sits structurally above the most distal and stratigraphically highest (youngest) CPS units. It comprises ocean floor lithologies which were highly deformed and metamorphosed prior to intrusion of supra-subduction zone trondhjemites at ~515 Ma and possibly also by magmatic rocks of the Bay of Islands ophiolite. This implies that by 515 Ma, the Coastal Complex occupied an upper plate position, and a subduction zone was active and located between the Laurentian margin (i.e., the lower plate) and the Coastal Complex (Fig. 5c). The composition and deformation of the Coastal Complex – which resemble that of a small segment of an OPS-derived accretionary prism – imply that the Coastal Complex records the existence of older subduction that led to accretion of oceanic floor: the Coastal Complex represents an accretionary prism that developed above a subduction zone before 515 Ma (Fig. 5a). Furthermore, the Coastal Complex comprises deformed oceanic units with supra-subduction zone signature: this implies that the oceanic units accreted to the prism originally developed in an upper plate position and later became the lower plate before accretion. The age of this prism is unknown, but it is possible that it formed by subduction below the Laurentian margin prior to opening of a back-arc basin within that margin (Fig. 5b). Opening of the basin then separated the Laurentian margin from its accretionary prism. Note that the Coastal Complex then provides the sole evidence on Newfoundland of such a west-dipping subduction zone before the Ordovician. By 515 Ma, eastward subduction initiated within the back-arc basin, i.e. a subduction polarity switch, leaving the Coastal Complex 'fossil' prism in an upper plate position (Fig. 5c).

The Bay of Islands Ophiolite, east of the Coastal Complex, yields a supra-subduction zone (SSZ) signature (Elthon 1991) and is floored by a metamorphic sole that testifies that such east-dipping subduction must have been ongoing by 490-485 Ma (Fig 4b, 5c) (Fournier-Roy *et al.* 2024; Yan and Casey 2023). Other soles in the region, for example the one beneath the St. Anthony ophiolite in northern Newfoundland (Fig. 3), exhibit similar cooling ages which may suggest it is a northern continuation of the Bay of Islands system. Ages of the mafic crust (i.e., from plagiogranites) of the Bay of Islands Ophiolite indicate that upper plate extension was underway by 488 Ma (Yan and Casey 2020), which may constrain the timing of slab roll-back of a mature subduction setting (Guilmette *et al.* 2018; 2023). As the Bay of Islands ophiolite intrudes into the Coastal Complex, forearc spreading must have been located within the 'fossil' accretionary prism (Fig. 5c).

We identified the location of an ancient subduction zone in our orogenic architecture diagrams and inferred that units on either side of this structure are lower plates (west) and upper plates (east). 'Finding' the subduction zone is the final ingredient required to reconstruct a complete Wilson cycle, beginning with continental break-up, drifting, subduction initiation, and westward thrusting and crustal accretion. Our architecture diagram captures this complete tectonic cycle for the western side of the orogen.

Moving farther east, the simplest hypothesis would be to find a geologic history that corresponds with other units in the same upper plate setting. Alternatively, we could identify a change from upper to lower plate setting, which would indicate either that we crossed a suture, or that the 'Bay of Islands' upper plate acts as a lower plate in another, younger subduction system. We note that interpretations farther east will need to be further evaluated by accounting for dextral displacements of the Cabot Fault and, in this case, by correlations with the geology of the locations of origin once displacement is restored. However, because displacement is orogen-parallel, this will likely not change interpreted 2D geodynamic evolution significantly. We do not perform a detailed 3D analysis and 4D evolution in this paper, because our interpretation of Newfoundland only serves as a case study to explain the application of our methodology and is intended to only highlight data-based interpretations without necessarily present new ones. Furthermore, we note that strike slip displacement can account for the different tectonic history of the Internal Laurentian CPS units as preserved in the Fleur de Lys Supergroup in northern Newfoundland and in the Corner Brook Lake Block in central-western Newfoundland, and to account for the arc magmatism preserved in the restricted Coney Head Complex west of the Cabot Fault, which can be associated with the Bay of Islands ophiolite (though the Complex itself is understudied).

Lateral Paleogeographic Complexity and Records of Subduction in Upper Plate Units

Supra-subduction zone ophiolites (i.e., Baie Verte ophiolites) to the east record similar upper Cambrian ages (ca. 490 Ma) as the Bay of Islands complex and are overlain by volcano-sedimentary magmatic arc sequences, indicating that they occupied a similar upper plate setting. The Notre Dame arc appears to have been an expression of the Bay of Islands (or Baie Verte) subduction zone, because it exhibits ages spanning the time window between self-sustained subduction as inferred from metamorphic ages of the Bay of Islands sole, and the end of subduction when the Laurentian continental margin arrived at the trench (Fig. 5). Moreover, the westernmost location of the Bay of Islands (proto)forearc ophiolites marks the easternmost possible location of the trench during subduction initiation; the Notre Dame arc is ~100 km east of this position, which is the minimum width of a typical forearc (Gill 1981; Stern 2002). This is a minimum width: it is possible that the forearc underwent shortening during accretion. How much this shortening may have been is unknown, but there are to our knowledge no documented examples of ophiolites that were tectonically duplicated and regionally thrusted over each other that could signal major shortening in Newfoundland. Upper plate ophiolites appear to regionally act as tectonic 'blankets' that cover thrusted, accreted units derived from downgoing plates (e.g., Arkula *et al.* 2023) and the maximum estimated amount of distributed oceanic (fore)arc shortening based on geological observations, in the northeastern Caribbean region, is ~75 km, or ~30% (Philippon *et al.* 2020).

The ~490-460 Ma Notre Dame arc intrudes the > 504 Ma Lush's Bight ophiolites in northern Newfoundland (Szybinski 1995), and the Dashwoods 'microcontinent' crust (that recorded metamorphism around 466-460 Ma) in southern Newfoundland (Fig. 4a, b), which we infer to highlight paleogeographic complexity along-strike of this tectonic system, as already interpreted before by several authors (e.g., van Staal *et al.* 2013; van Staal and Zagorevski 2020; van Staal and Dewey 2023). We note that the Lush's Bight ophiolites, Dashwoods microcontinental crust, and cross-cutting Notre Dame arc units are all preserved in a ~40 km-wide, northeast-southwest striking band with a coherent magmatic-sedimentary stratigraphic cover (Fig. 3), thus they may represent part of the same composite continental-oceanic lithosphere. If the Lush's Bight ophiolites represented evidence for an older subduction zone, it would require evidence of foreland basin clastics, regionally traced thrusts, or associated metamorphic rocks. No such phenomena are known here, so indeed the most straightforward interpretation is that this entire complex comprises remnants of a narrow strip of genetically related composite continental-oceanic lithosphere.

We thus interpret the Lush's Bight ophiolites in northern Newfoundland as remnants of the oceanic basin that opened east of the Laurentian margin in the late early Cambrian, and that occupied an upper plate position after subduction initiated within the basin, thus escaping subduction-related deformation and metamorphism (Fig. 5c). In southern Newfoundland, the same Notre Dame arc crosscuts very different (i.e., Dashwoods) micro-continental and/or meta-sedimentary basement rocks, but the underlying lithosphere exhibits zircon provenance indicative of a Laurentian source. These same metasediments do not overlie the Lush's Bight ophiolite to the north. This implies that these (meta-) sediments were initially deposited proximal to Laurentia but with a highly focused depocenter likely controlled by paleogeography and topographic divides. They then tectonically separated from Laurentia during the rift-to-drift phase described above and later became re-incorporated into the Laurentian margin during orogenesis. Therefore, the Dashwoods (meta-) sedimentary rocks and Lush's Bight ophiolite may well have been part of the same strip of lithosphere that was separated from the continental Laurentian margin in the middle Cambrian. Furthermore, if the Coastal Complex represents a fossil accretionary prism that formed along the Laurentian margin, then the Dashwoods metasediments – and the slivers of ultramafic units that are present in the same area of southwestern Newfoundland – could be part of the same prism, rifting off Laurentia together upon opening of the Cambrian oceanic (back-arc) basin. Upper plate extension and formation of the Bay of Islands ophiolite then separated the Coastal Complex from Dashwoods (Fig. 5c). As previously mentioned, we note that this interpretation needs to be evaluated carefully, as Dashwoods lies to the east of the Cabot Fault, and is correlated to the Coastal Complex which lies to the west of it. Although orogen-parallel displacement might not substantially modify the 2D structural evolution, a large displacement along this fault might mean that this interpretation of Dashwoods will need to be further evaluated through correlations with the Laurentian margin geology of the location it would have originally been east of (i.e., west of the British Isles, based on zircon provenance studies; Hodgin *et al.* 2022; Zagorevski *et al.* 2024), in order to check if the interpretation remains valid. A similar evaluation would be needed to account for the forearc-arc distance between the Bay of Islands and the Notre Dame Arc.

The Annieopsquotch Tract outboard of Lush's Bight and Dashwoods is another ophiolitic-arc system that affirms the upper plate setting continues to the east. The ophiolitic units are younger than those of the Baie Verte and Bay of Islands, suggesting they formed after subduction initiation. An interesting inference from the relative positions and ages of the Annieopsquotch Tract is that it requires eastward ridge jump around ca. 481 Ma, with the spreading center relocating outboard of the crustal block represented by Dashwoods and Lush's Bight (Fig. 5e). This is justified because older (middle-Cambrian) oceanic (Lush's Bight) or microcontinental crust (Dashwoods) sits between portions of younger (upper Cambrian-Early Ordovician) oceanic lithosphere represented by the Bay of Islands-Baie Verte ophiolites and the Annieopsquotch Tract.

Structurally, the Annieopsquotch Tract poses further complexity: the units occupy an east-verging thrust stack, which is the opposite sense of movement than recorded in the west, along the Laurentian margin. This could possibly indicate backthrusting when the Laurentian continental margin arrived at the subduction zone and was dragged beneath the BOIC forearc-Notre Dame arc-Annieopsquotch backarc upper plate system. Alternatively, it could reflect a west-dipping subduction zone to the east of the Annieopsquotch Tract. In fact, SSZ signatures in the Coastal Complex and Lush's Bight ophiolite may indicate that a subduction zone operated from the middle Cambrian onwards. Moreover, the older Notre Dame Arc units are intruded by Late Ordovician-early Silurian magmatic units, some of which yield arc signatures (Whalen *et al.* 2006). This magmatic age does not fit with the east-dipping subduction zone in the west, because that system ended by the Upper Ordovician (i.e., post-tectonic sedimentation), but it could support the presence of another west-dipping subduction zone to the east by the early Silurian.

Iapetus Ocean And Gondwana-Derived Units

The first units derived from Gondwana appear in the footwall of a top-east thrust stack across the Beothuk Lake Line that emplaces the Annieopsquotch Tract (Williams *et al.* 1988; 1995; White and Waldron 2022) above arc and continental units contain fossil fauna characteristic of the Gondwanan margin (e.g., Harper *et al.* 2009; Hibbard *et al.* 1977; van Staal *et al.* 1998). Therefore, we interpret the thrust between the Annieopsquotch Tract and underlying Gondwana-derived sedimentary and igneous units as a suture marking the disappearance of the Iapetus Ocean that separated the two continents. Remarkably, we did not identify any widespread units interpretable as an accretionary prism containing OPS of the Iapetus Ocean anywhere in Newfoundland. The only unit which may represent an accreted sliver of Iapetus is the restricted alkali basalt unit in the eastern Robert's Arm belt in northern Newfoundland (see Annieopsquotch Tract section above).

The structure of Gondwana-derived units is relatively more complex than that of units derived from the Laurentian margin. However, its structure and geological history appear to be a mirror image of the Laurentian margin (Williams 1964), but slightly older. The westernmost Gondwana-derived units of the Victoria Lake CPS comprise a crystalline basement (the Sandy Brook Group and Crippleback Intrusive Suite) overlain by the Cambrian Penobscot Arc magmatism (McNicoll *et al.* 2008). East of the arc, mid-late Cambrian ophiolites were thrust upon the Ganderia continental margin. Since the Penobscot Arc was not obducted, the ophiolites were likely derived from an ocean basin that opened between the composite Sandy Brook Group-Penobscot Arc unit and the Ganderia margin to the east. This could have been a back-arc basin above an east-dipping subduction system beneath Gondwana at the eastern extent (in present-day coordinates) of the Iapetus Ocean (e.g., van Staal *et al.* 1998; Zagorevski *et al.* 2010) (Fig. 5d). In turn, thrusting and metamorphism of the back-arc basin basalts over the Gondwanan margin might indicate the presence of a west-dipping subduction zone (present coordinates); alternatively, they could simply be a result of backthrusting of the back-arc basin above the continental margin. The ophiolites were thrust on top of the westernmost portion of the Gondwana margin (i.e., Ganderia) but did not reach the more inboard part (i.e., Avalonia): this might provide a possible explanation as to why Ganderia records a stage of deformation-metamorphism that Avalonia does not (Fig. 5e, f).

Based on the orogenic architecture diagrams, we can draw the following correlations between the Laurentian and Gondwana sides of the margin: (1) the Sandy Brook Group-Crippleback Intrusive Suite is equivalent to the Dashwoods continent; (2) the Pipestone Pond, Coy Pond, and Gander River ophiolites are equivalent to the Bay of Islands ophiolite (if they formed as SSZ ophiolites above the subduction zone that formed within the back-arc basin) or the Lush's Bight ophiolite (if they represent the original back-arc basin crust); (3) the Ganderia (micro)continent is equivalent to the internal Laurentian CPS units; and (4) the Avalonian crust is equivalent to the external Laurentian CPS units.

There is no direct geologic evidence that Avalonia and Ganderia were once separated by an ocean, or by a subduction zone, in Newfoundland. The Silurian-Early Devonian arc magmatism intruding Ganderia units west of the Dover-Hermitage Bay Fault provides evidence of subduction continuing east of Ganderia after it had accreted to the Laurentian upper plate but does not offer further information on the location of such subduction zone. According to the orogenic architecture, 'Avalonia' could be interpreted as an eastward, non-metamorphosed continuation of 'Ganderia' and was just another part of the train of continental fragments that rifted away from Gondwana and migrated westward on the same plate (Fig. 4 and 5).

The volcano-sedimentary sequences, thrust imbrication, and deformation-metamorphism recorded in the Gondwanan margin units are diagnostic of an orogenic event that was completed by 470 Ma, constrained by the age of the Ganderia Overstep sedimentary Sequence. This is 30 million years *before* these units arrived at the Laurentian margin, as indicated by the Laurentian zircon signature in the flysches of the Upper Ordovician-lower Silurian Badger Group, overlying the Victoria Arc CPS units. The Lower Ordovician orogeny effectively created a composite 'CPS' basement for the younger sediments and magmatic rocks. For example, syn-rift clastics of the Ganderia Overstep Sequence indicate rifting, and may reflect rifting of the Ganderia-Avalonia microcontinent(s) from Gondwana. Mid-Ordovician mafic volcanic rocks of the Ganderia Overstep Sequence (i.e., the basalts of the Red Cross and Baie d'Espoir Groups) further testify to this rifting and lithospheric thinning. Furthermore, Upper Ordovician? volcanic units of oceanic affinity in the Duder Complex and Hamilton Sound Group in northern Newfoundland, and of the Pine Falls Formation farther south, may represent the opening of such oceanic basin, though information on these units is scarce. Based on the geographical location of the units, this basin may have separated the Ganderian units in two CPS sequences (i.e., the one containing the Victoria Arc and a second one, where the Ganderia Overstep Sequence deposited). Arc magmatism of the Victoria Arc units directly to the west is coeval with the Ganderia Overstep Sequence to the east, indicating that they occupied an upper plate setting and thus that east-dipping subduction was active below the Gondwana-derived microcontinent(s) in the Lower-Middle Ordovician and was coeval with rifting of the microcontinents (Fig. 5f).

The Victoria Arc is located immediately east of the Iapetus suture (Beothuk Lake Line, Fig. 3), which implies that the forearc of this subduction zone, and possibly an accretionary prism preserving slivers of the Iapetus Ocean, was either removed by subduction erosion or buried beneath the Annieopsquotch Tract. This east-dipping subduction zone below Ganderia/Avalonia consumed the intervening ocean basin until the Gondwana-derived units arrived at the Laurentian margin in the Upper Ordovician (Fig. 5g). The youngest arc ages are rapidly succeeded by foreland basin, Laurentian-derived siliciclastic deposits (Badger Group) of Upper Ordovician-Llandovery age which capture the 'docking' phase. After accretion of the Gondwanan-derived Victoria Arc, early-late Silurian volcanoclastic and terrestrial sediments deposited on both sides of the Iapetus suture (i.e., Springdale Group overlying the Notre Dame Arc and Annieopsquotch units, and the Botwood Group overlying the Victoria Arc), testifying to the final closure of the Iapetus Ocean and to the end of accretion (Fig. 5h).

To the east of the Victoria Arc, sedimentation of Ganderia Overstep Sequence continued with a marine to terrestrial sequence (Indian Islands Group) until the early Devonian. In contrast with the Badger Group, there are no clear foreland basin deposits of Upper Ordovician-Llandovery age in the Ganderia Overstep Sequence, where the only sediments attributable to foreland basin sedimentation may be turbiditic sandstone lithologies of the Davidsville Group; this may be due to distance from the foreland resulting in a different sedimentary setting. There is also no evidence of foreland basin deposits of younger age that may indicate subduction of an oceanic basin located between the Victoria Arc and Ganderia Overstep Sequence. The Upper Ordovician-Silurian pelagic and clastic sediments (Indian Islands Group) of the Overstep Sequence indicate that this sedimentary setting was initially marine. There is no further evidence in Newfoundland to infer the existence of a Silurian subduction zone (in the form of a developed accretionary prism, upper plate ophiolites or widespread flysch deposits) which consumed this basin, thus its existence cannot be independently confirmed.

DISCUSSION

In the previous section, we synthesized our 'orogenic architecture diagrams' and interpreted a first-order paleogeographic and tectonic reconstruction of the Newfoundland Appalachians based on compiled stratigraphy, magmatism, geochemistry, and metamorphism data. Our reconstruction shows that the Laurentian margin records a complete Wilson cycle, which agrees strongly with most previous interpretations (e.g., van Staal *et al.* 1998; van Staal and Barr 2012; Waldron and van Staal 2001; White and Waldron 2022). This affirms that orogenic architecture diagrams provide a useful approach to reconstruct plate tectonic and paleogeographic history. Interestingly, our interpretation deviates in several ways from the most accepted models of Northern Appalachian orogenesis. Here we highlight and discuss three of the multiple discrepancies that illustrate how our method may provide a useful tool to (re)assess previous interpretations and identify the key observations that underlie contrasting views.

Did Dashwoods and Lush's Bight Occupy The Same Upper Plate?

In our reconstruction, Lush's Bight ophiolites make up part of the ocean between Laurentia and the Dashwoods microcontinent (i.e., the Taconic Seaway; e.g., Hibbard *et al.* 2007; van Staal *et al.* 2007); in most previous reconstructions, Lush's Bight formed in the forearc above a middle-late Cambrian, west-dipping subduction zone within the Taconic Seaway and was thrust eastward over the Dashwoods terrane (e.g., Szybinski 1995; Swinden *et al.* 1997; Zagorevski and van Staal 2011). However, we did not identify any unequivocal evidence of Lush's Bight obduction in northern Newfoundland: the contacts of the Lush's Bight units are mostly obscured by Notre Dame Arc intrusions; no metasediments of the Dashwoods continent are exposed; and Dashwoods is approximately 40 km wide (less than half of a typical lithospheric thickness) which is small even for microcontinents (Péron-Pinvidic and Manatschal 2010).

The argument for obduction is mostly based on correlations with other ophiolitic complexes such as the St. Anthony ophiolite and Long Range mafic-ultramafic complex (van Staal *et al.* 2009; van Staal and Barr 2012). The St. Anthony ophiolite, for example, has a sole with a metamorphic age of 495 Ma, which has been interpreted as the age of emplacement atop the Laurentian margin (Jamieson, 1988; van Staal *et al.* 2009; van Staal and Barr 2012). However, recent studies suggest that the age of metamorphic soles records subduction initiation, rather than the age of thrusting over a continental margin (e.g., Guilmette *et al.* 2018). The St. Anthony Complex may therefore be a northern equivalent of the Bay of Islands Ophiolite, since it has similar metamorphic sole ages and a similar structural position above allochthonous units of the Laurentian margin (Fig. 3).

Another argument for Lush's Bight ophiolite obduction is a proposed correlation with the Long Range mafic-ultramafic Complex and with other restricted ultramafic units in southern Newfoundland (Dubé *et al.* 1996; Lissenberg *et al.* 2006). However, these units lack age or geochemical constraints except for being intruded by late Cambrian plutons of the Notre Dame Arc, so correlations with Lush's Bight are inferred from the geographic locations of the two ophiolitic complexes within the same 40-km wide zone. Both may well be part of the same lithosphere.

Finally, calc-alkaline dykes of 504-495 Ma age that are apparently contaminated by continental crust crosscut lithologies of the Lush's Bight ophiolite, which is taken as evidence that Lush's Bight was thrust atop continental material of the Dashwoods terrane (Szybinski 1995; Swinden *et al.* 1997; van Staal *et al.* 2009). However, a 'continental' fingerprint is not necessarily diagnostic of Dashwoods per se but could also derive from the continental crust of Laurentia *sensu stricto*, or subducted Laurentian-derived sediments.

We argue that the geology of Newfoundland does not contain unequivocal evidence for a west-dipping subduction zone within the Taconic Seaway in the middle-late Cambrian. Rather, with the available data, a more straightforward interpretation could be made where the Lush's Bight sequence is part of the Taconic (back-arc) basin floor that also separated the Dashwoods microcontinental fragment from the Laurentian margin – the two are lateral equivalents of the same microplate (Fig. 5b).

What Was the Subduction Polarity of The Iapetus Ocean?

Our reconstruction highlights the very little evidence for westward subduction of the Iapetus Ocean, only represented by the Coastal Complex accretionary prism, the restricted alkali basalt units in the Robert's Arm belt of the Annieopsquotch Tract, and Late Ordovician-early Silurian arc magmatism; however, west-dipping subduction of the Iapetus Ocean below Laurentia is commonly envisioned from the Lower Ordovician onwards (van Staal *et al.* 2007, 2009; Zagorevski *et al.* 2008; Zagorevski and van Staal 2011; van Staal and Barr 2012). In the following, we discuss evidence of Iapetus subduction in Newfoundland at different time periods.

Cambrian. The Coastal Complex may represent the only widespread exposed early Cambrian record of accreted remnants of the Iapetus Ocean. It has previously been interpreted as representing an arc unit amalgamated in a transform setting (Suhr and Cawood 2001) or as juvenile forearc lithosphere of the east-dipping subduction of the Taconian Seaway (e.g., Yan and Casey 2020, 2022), and its deformation as the result of e.g. obduction processes (e.g., Karson and Dewey 1978; Karson

1984; Yan and Casey 2022). However, the deformation and metamorphism of the Coastal Complex predate the formation of the Bay of Islands Ophiolite and thus requires an older ocean floor formation and destruction phase before 514-503 Ma (Yan and Casey 2022). Our alternative interpretation is that the Coastal Complex is an OPS-derived accretionary prism derived from westward subduction of Iapetus Ocean below the Laurentian margin. Such westward subduction of the Iapetus Ocean may then explain the opening of the Taconic Seaway due to rollback, and the separation of the Coastal Complex and Dashwoods accretionary prism as a 'microcontinent' from the Laurentian margin. This may be comparable to the separation of the Palawan 'continental terrane' - a Mesozoic accretionary prism that formed along the South China margin, during the Cenozoic opening of the South China Sea (e.g., Shao *et al.* 2017; van de Lagemaat *et al.* 2024), or the Japan accretionary prism from Eurasia during the Cenozoic opening of the Sea of Japan back-arc basin (Isozaki *et al.* 1990). Despite this, no arc units or forearc ophiolites of this age are preserved on the margin of Laurentia, thus the polarity and extent of Iapetus subduction in the early Cambrian remain mostly unconstrained.

Lower-Middle Ordovician. Following initiation of subduction within the Taconian Seaway, which, according to our interpretation from the diagrams, occurs with a polarity switch, the only pieces of evidence for continued west-dipping subduction of the Iapetus Ocean east of Dashwoods are represented by west-dipping imbrication of the Laurentian-Notre Dame-Annieopsquotch units, and (possibly) fault-bound alkali basalts in the Robert's Arm belt of the Annieopsquotch Tract, which are interpreted as an accreted seamount (Zagorevski and McNicoll 2012) but have not been dated. No other conclusive evidence exists for this subduction zone. In many interpretations, the arc associated with the west-dipping subduction zone is the narrow, Early-Middle Ordovician Notre Dame - Annieopsquotch sequence. These arc magmatic sequences are typically interpreted as two different arcs (Swinden *et al.* 1997; Lissenberg *et al.* 2005a, b; Zagorevski *et al.* 2006; van Staal and Barr 2012) that would have become juxtaposed after subduction of an originally intervening ocean floor. The arc sequences of the Annieopsquotch Tract could then have been accreted as thrust slices offscraped from the subducting plate and become structurally juxtaposed with the Notre Dame Arc. Juxtaposition of two arc sequences is not an unknown process, but it requires (1) subduction erosion of the full forearc associated with the upper-plate arc, (2) subduction of the oceanic lithosphere separating the two arcs (with accretion of OPS units to a fold-and-thrust belt), and (3) deposition of foreland basin deposits on top of the downgoing-plate arc. This is, for example, the case of the Fossa Magna in eastern Japan, where the Izu-Bonin Arc is subducting below the Japan Arc (e.g. Kimura 1996; Taira 2001; Arai *et al.* 2009). However, the Annieopsquotch-Notre Dame terrane contains no evidence for such a protracted history of subduction between accretion of two arc-derived nappes, as no accreted OPS units are preserved, and as the two arc nappes of the Annieopsquotch Tract are not overlain by foreland basin sequences of different age. It is thus more straightforward to interpret the two time-equivalent arc sequences as the deformed remains of a single arc that formed above a single subduction zone. Most of the arc magmatic units developed during subduction of the Taconic Seaway and the Laurentian margin and are temporally equivalent to the accretionary complex between the Bay of Islands ophiolite and the Laurentian foreland. The distance between the western margin of the Bay of Islands ophiolites and the Notre Dame-Annieopsquotch arc sequences is at present ~100 km, within the range of typical arc-trench distances (Stern 2002). This is a minimum width, as the Annieopsquotch sequence has been shortened, but the arc complex fits well with the east-dipping 'Taconic' subduction zone, although detailed interpretation needs to take displacement along the Cabot Fault into account. If, however, the Annieopsquotch Tract represents an arc related to west-dipping Iapetus subduction (Swinden *et al.* 1997; Zagorevski *et al.* 2006; van Staal and Barr 2012), this poses a geodynamic difficulty; that would imply two simultaneously operating, opposite polarity subducting slabs (i.e., the eastward subducting Taconic seaway and the westward subducting Iapetus Ocean) that would collide at depth. In this case, the two arcs would have had to be separated by lithosphere that would since have subducted, leaving them juxtaposed. As mentioned above, there is no evidence in the Notre Dame-Annieopsquotch units of such a hypothetical subduction zone. Thus, a west-dipping slab of Iapetus in the *late Cambrian to Middle Ordovician* is not a straightforward interpretation, and it is hard to reconcile with the geological record as exposed in Newfoundland.

Late Ordovician-early Silurian. Arc units of Late Ordovician-early Silurian age are locally preserved in the same narrow upper plate strip, which post-date the subduction of the Laurentian margin, and predate the final deposition of foreland basin deposits on the Victoria Arc (Fig. 4) (Waldron *et al.* 2012). These units may indicate a west-dipping subduction zone beneath Laurentia at this time. The foreland basin sequences imply that the Victoria Arc and Ganderia-Avalonia occupied a downgoing plate position. Their lower plate setting may explain why the original forearc of the peri-Gondwana system, that must have separated the Victoria arc from its associated trench, is not preserved, as it could have been fully subducted in the west-dipping subduction below composite-Laurentia. A similar forearc would also have existed on the Laurentian side, adjacent to where the arc – i.e., the Buchans and Beothuk Lake Groups of the Annieopsquotch Tract – is located next to the Beothuk Lake Line; this forearc could have been obducted and eroded, or removed by subduction erosion.

Were Ganderia and Avalonia part of the same microplate in the Ordovician?

Plate reconstructions commonly depict the early Paleozoic orogeny resulting from the collision of several Gondwana-derived microcontinents with the margin of Laurentia, including Ganderia and Avalonia (e.g., Torsvik 1998; Domeier 2016; Merdith *et al.* 2021; Scotese 2023). However, the evidence summarized in our orogenic architecture diagrams shows that there is no record of a relict ocean basin or subduction zone between Ganderia and Avalonia in Newfoundland that postdates their breakup from Gondwana. Similarly, the evidence for the existence of subduction of an oceanic basin between the Victoria Arc and the sedimentary units of the Ganderia Overstep Sequence in Newfoundland is rather scarce, though an oceanic basin is commonly envisioned from the Middle Ordovician up to the Silurian (e.g., van Staal and Barr 2012; van Staal *et al.* 2021a).

The interpretation that Ganderia and Avalonia are two separate microcontinents is largely based on lithological differences between their basements and their Cambrian sedimentary successions at the scale of the Appalachian-Caledonian orogenic belt (e.g., van Staal and Barr 2012; van Staal *et al.* 2021a). These differences mostly stem from Neoproterozoic basement ages and compositions, where rocks of the Ganderian basement are isotopically more evolved than Avalonia (Rogers *et al.* 2006; van Staal *et al.* 2012, 2021a; Waldron *et al.* 2022), and these may well suggest that the blocks have once been microcontinents with separate histories (although also that is debated, e.g., Landing *et al.* 2022). Since there is no evidence for Cambrian seafloor between Ganderia and Avalonia in Newfoundland, the simplest interpretation of our orogenic architecture diagrams is that differences in the Neoproterozoic-lower Paleozoic lithological records of Ganderia and Avalonia relate to accretionary orogenesis along the Gondwana margin and could be unrelated to the Appalachian accretionary history.

Furthermore, in our diagram interpretation we have hypothesised that the lithological differences between the sedimentary sequence overlying the Victoria Arc (i.e., the flysches of the Badger Group) and the Ganderia Overstep Sequence (which lacks Upper Ordovician flysch deposit), may be the result of distance from the foreland and thus a different sedimentary setting; in the literature, this difference is instead attributed to a backarc basin located between the Victoria Arc and the Overstep Sequence which then closed by subduction along the Dog Bay Line in the Silurian (e.g., Currie 1995; Williams *et al.* 1993; Valverde-Vaquero *et al.* 2006a). According to these studies, the Victoria Arc and Ganderia Overstep Sequence represented two different microcontinental blocks which accreted to composite Laurentia separately, in the Late Ordovician and late Silurian, respectively (e.g., van Staal and Barr 2012). This inference is supported by the existence of restricted units of oceanic affinity (i.e., the Duder Complex, Hamilton Sound Group and Pine Falls Formation) on the western side of the Overstep Sequence (e.g., Zagorevski *et al.* 2010; van Staal *et al.* 2014), and by the lack of Victoria Arc detrital signature within the Overstep Sequence (e.g., Pollock *et al.* 2007), which requires that a sedimentary divide existed between the two sedimentary sequences. However, such oceanic units are rather understudied, and no ophiolites or clearly defined flysch sequences of ages younger than the Upper Ordovician are preserved along the Dog Bay Line or east of it, thus its nature as a suture, and the nature and timing of the accretion of the Ganderian block(s) does not independently follow from the architecture of Newfoundland alone. This interpretation may follow from the geology of the orogen farther south (e.g., van Staal and Barr 2012).

Finally, after this whole orogen had become part of Laurentia in the early Silurian, it became 'upper plate' during the closure of the ocean that opened between Avalonia/Ganderia and Gondwana (the Rheic ocean) towards the formation of Pangea (e.g., Domeier 2016). The late Silurian and Devonian magmatism in Newfoundland are likely related to this history. Subsequently the orogen became the "basement" of the next syn-rift sediments, in the next Wilson cycle (Wilson 1966), that started with the Jurassic opening of the Central Atlantic Ocean (e.g., Tucholke *et al.* 2007), and that still awaits its subduction and closure phase.

These interpretations are based on geologic records from Newfoundland only, so applying the orogenic architecture concept to other areas of the Appalachian-Caledonian orogenic belt (i.e., the British Isles or mainland Canada), or paleomagnetic constraints, may justify a more complete (plate) tectonic history.

Benefits Of Orogenic Architecture Diagrams

The orogenic architecture approach provides a useful tool to systematically synthesize geological data into a reproducible framework for paleogeographic and tectonic reconstructions. We applied this methodology to the Appalachian orogen in Newfoundland and demonstrated that it provides a basis for data-driven reconstructions of complex tectonic histories, and that it facilitates orogen-scale interpretations (Fig. 6). Having all available geologic data in one digestible diagram encourages scrutiny of our own interpretations and of past interpretations.

The concept of orogenic architecture diagrams was first developed for Mesozoic-Cenozoic orogens in the Tethyan and Pacific regions (Isozaki *et al.* 1990; Handy *et al.* 2010; van Hinsbergen *et al.* 2020; Boschman *et al.* 2021; van Hinsbergen and Schouten 2021; Advokaat and van Hinsbergen 2024). For Neoproterozoic-Paleozoic Newfoundland, we applied the same general classification scheme of continental plate, oceanic plate, and ophiolite units (CPS/OPS/ophiolites); used the same strategies for identifying upper and lower plate units; and similarly distinguished geological expressions of rifting and oceanic and continental subduction. This demonstrates that early Paleozoic orogens still behave according to modern-day plate tectonics, which is the fundamental paradigm underlying the orogenic architecture diagrams approach. Incomplete preservation and exposure of the geological archive and a substantial number of orogenic episodes may however hinder the use of the diagrams and complicate reconstructions, especially for increasingly older orogens. Nevertheless, where preservation allows it, the orogenic architecture diagram approach may still provide a method to evaluate different geological expressions of plate tectonics in a hotter, more juvenile Earth, and when and where assumptions rooted in the theory of modern plate tectonics – i.e., the basic hypothesis our methodology is based on – start to break down. This may shed a new light on debates on the origin, evolution, and expression of plate tectonics throughout Earth's history.

A particular advantage of our approach is that it highlights the underlying geologic observation or data that sources discrepancies in interpretations. Therefore, data-based interpretations naturally emerge that comply with the current paradigm of plate tectonics and plate boundary deformation. As such, it provides a means to identify targets for future research. Reconstructions can be further tested against paleomagnetic data that constrain convergence and divergence unaccounted for in the accretionary record.

In agreement with previously published interpretations (e.g., Zagorevski and van Staal 2011; van Staal and Zagorevski 2020), an interesting finding that emerges from our reconstruction of Newfoundland is that the structure and metamorphism preserved in the orogen mostly reflect accretion and ophiolite emplacement, rather than continent-continent collision. 'Collision' between Laurentia and Ganderia/Avalonia – the final Gondwana-derived block to arrive – at the end of orogenesis is poorly preserved in Newfoundland and did not impart extensive evidence of regional metamorphic or structural features. To address this issue, along strike comparisons must be made, as evidence for collision may be more significant in mainland Canada and New England (e.g., van Staal *et al.* 2009; van Staal and Barr 2012). Orogenic architecture diagrams thus permit the recognition of areas of uncertain interpretation and their potential equivalents along strike, and provide a way to make comparisons to corroborate or contradict such interpretations.

As a further example of this, we highlight the uncertainties regarding the Dog Bay Line, which separates structural units with different Upper Ordovician-Silurian sedimentary history and is regarded in the literature as a major suture (see detailed discussion in the previous section). Through our approach, we have recognized the lithological and provenance differences and the presence of few units of oceanic affinity, but we argued that there is a lack of evidence to support the existence of a subduction zone along the Dog Bay Line *in Newfoundland*, as no ophiolites or widespread flysch units are preserved there. However, such evidence exists in New Brunswick, where the Brunswick Subduction Complex, comprising imbricated metamorphic ocean floor lithologies and their sedimentary cover overlain by siliciclastic deposits, suggests the existence of such an oceanic basin and such a subduction zone (e.g., van Staal *et al.* 2008; van Staal and Barr 2012; Wilson *et al.* 2015; van Staal *et al.* 2016). Application of the orogenic architecture diagram approach to other along-strike transects and, in particular, identification of ophiolites and/or OPS units located structurally between the Victoria Arc and Ganderian units, thus confirms that the Dog Bay Line represents a suture and therefore leads to a more complete paleogeographic configuration of basins and subduction zones during the orogeny.

A similar reasoning could be applied to further address the lack of evidence of an oceanic basin between Ganderia and Avalonia in Newfoundland. Although the Silurian-Early Devonian arc plutons

intruding the Ganderian units give an indication that subduction continued east of Ganderia, the location of such subduction zone is unknown, and the interpretation of Silurian subduction of Avalonia under Ganderia cannot thus derive from the evidence of Newfoundland alone.
Our example of the Newfoundland orogen merely serves to illustrate that a complete tectonic history based on all available information is objectively possible, and that a more-complete understanding of the orogen benefits from multiple orogen-scale cross section lines to characterize lateral complexities relevant for geodynamic and kinematic plate reconstructions. In the case of the orogeny associated with Iapetus Ocean closure, the most recent Paleozoic plate model (Domeier 2016) mainly based their reconstruction on paleomagnetic data, and only briefly reviews the architecture of the orogen. The architecture that was considered was based on the most widely accepted interpretations, which are not always justified by the synthesized geologic record. Our new geological review can be the basis for further integration throughout the entire orogenic belt, and with paleomagnetic data, can pave a way forward for improving the plate model. Ultimately, this approach of integrating records of stratigraphy, composition, geochemistry, structure, and metamorphism, free of a-priori interpretations, can form the basis for geodynamic and kinematic plate reconstructions on a global scale.

CONCLUSIONS

Accretionary orogenic complexes comprise remnants of lithosphere that was consumed by subduction in the geological past and typically record protracted histories and tectonic stages spanning tens of millions of years. Interpretations of geological records are a prerequisite for paleogeographic and plate tectonic reconstructions but can be complicated by the multidisciplinary nature of available geologic information, including paleontology and sedimentology, stratigraphy, paleomagnetism, geochemistry, deformation, and metamorphism. Many famous orogens worldwide are explained by a variety of contradicting interpretations that arise from efforts to reconcile disparate datasets of a variety of different disciplines. In an effort to objectify data syntheses and paleogeographic and tectonic interpretations, we outlined the working principles of a method that compiles data across disciplines at the scale of individual structural units, which form the building blocks of accretionary orogens. This serves as a mesoscale step between detailed field and laboratory analyses and large-scale plate reconstructions. We developed a template and protocol for creating so-called 'orogenic architecture diagrams' and apply the method to the Appalachian belt in Newfoundland as a case study. Our findings are the following.

- For each fault-bound unit, we compile (where relevant) lithological, stratigraphic, structural, geochronological, geochemical, and metamorphic data, and plot the data with simple symbology against geological time. We distinguish ‘lower plate’ Continental Plate Stratigraphy (CPS) or Ocean Plate Stratigraphy (OPS) from ‘upper plate’ ophiolites; upper plate ophiolites are locally associated with lower-plate slices (i.e., metamorphic soles) formed during subduction initiation. Upper plate units can consist of accreted CPS or OPS, and/or magmatic rocks of earlier tectonic phases.
- By recognising key structural features such as faults, stratigraphic repetitions and lithological correlations, orogenic architecture diagrams further reveal when and in what order these building blocks were structurally juxtaposed along faults. Strike-slip structures – where displacement is significant – also represent an important marker to account for lateral movements and restore the location and geometry of accretion of the building blocks.

- We apply this method to the Appalachian belt in Newfoundland, Canada, which has long been interpreted as an orogenic belt resulting from accretion of Gondwana-derived continental rocks to the Laurentian margin via closure of the Iapetus Ocean and other marginal ocean basins. The diagrams clearly identify phases of rifting and ocean basin opening; the subsequent closure of oceans associated with ophiolite emplacement and margin thrusting; and metamorphic signatures indicative of a complete 'Wilson-cycle'-style along both the Laurentian margin (Cambrian to Middle Ordovician) and the Gondwana margin (Cambrian to Early Ordovician). Subsequent rifting of the Gondwanan margin and subduction carried fragments of the Gondwanan orogen to the Newfoundland margin, where they arrived in the Late Ordovician-early Silurian according to the youngest foreland basin sequences in the orogen.
- The geological record of Newfoundland is comprised of the closure of marginal basins (e.g., Karig 1971), i.e., it records accreted units associated with back-arc opening and closure. Remarkably, there is no definite geological record of the vast Iapetus Ocean, but its presence is required due to differences in fossil fauna provenance and basement characteristics and, although not addressed here, paleomagnetism (Domeier 2016; Swanson-Hysell and MacDonald 2017). The subduction polarity of the Iapetus Ocean is inferred based on geochemical and stratigraphic arguments from the marginal geology.
- Most deformation and metamorphism recorded in Newfoundland resulted from subduction and ophiolite emplacement. Continent-continent collision is not preserved in the metamorphic record and represents only the final event in the orogenic process in a ‘soft docking’ manner.
- We illustrate that orogenic architecture diagrams are useful tools to comprehensively synthesize data and support data-driven interpretations at the orogen scale. This provides a base for larger scale paleogeographic, tectonic plate kinematic reconstructions. We highlight differences between our interpretations (based solely on the diagrams, purposefully ignoring past interpretations) and previously published models to illustrate how the orogenic architecture diagram approach illuminates the source of interpretation discrepancies. This in turn aids in identifying objectives for future research.
- Our methodology expands upon similar efforts applied to Mesozoic-Cenozoic orogens. We find that the paradigm of plate tectonics applies well to the early Paleozoic orogens studied here. Applying the same methods and theories to increasingly older orogens may unveil time frames in which the modern-day paradigm of plate tectonics can still be applied through Earth’s history, and to probe the emergence of (modern style) plate tectonics on a cooling planet.

ACKNOWLEDGEMENTS

AM acknowledges funding by the European Union under the *ForMovFluid* Doctoral Networks Programme (MSCA-DN-101168931) within the Horizon Europe Marie Skłodowska-Curie Actions, AJK acknowledges NWO-Veni grant NWO VENI Grant 222.097, and CG acknowledges NSERC funding (grant RGPIN-2020-06400).

We sincerely thank the reviewers for their time in assessing this manuscript and their constructive and valuable comments and suggestions, which greatly helped improve the quality of the manuscript.

REFERENCES

Advokaat, E.L. and van Hinsbergen, D.J.J. 2024. Finding Argoland: Reconstructing a microcontinental archipelago from the SE Asian accretionary orogen. *Gondwana Research*, **128**, 161–263, https://doi.org/10.1016/j.gr.2023.10.005.

Álvaro, J.J. 2021. Cambrian syn-rift tectonic pulses at unconformity-bounded carbonates in the Avalon Zone of Newfoundland, Canada. *Basin Research*, **33**, 1520–1545, https://doi.org/10.1111/bre.12525.

Anonymous. 1972. Penrose field conference on Ophiolites. *Geotimes*, **17**, 24–25.

Arai, R., Iwasaki, T., Sato, H., Abe, S. and Hirata, N. 2009. Collision and subduction structure of the Izu–Bonin arc, central Japan, revealed by refraction/wide-angle reflection analysis. *Tectonophysics*, **475**, 438–453, https://doi.org/10.1016/j.tecto.2009.05.023.

Arkula, C., Lom, N., et al. 2023. The forearc ophiolites of California formed during trench-parallel spreading: Kinematic reconstruction of the western USA Cordillera since the Jurassic. *Earth-Science Reviews*, **237**, https://doi.org/10.1016/j.earscirev.2022.104275.

Arnott, R.J. 1983. Sedimentology of Upper Ordovician-Silurian sequences on New World Island, Newfoundland: separate fault-controlled basins? *Canadian Journal of Earth Sciences*, **20**, 345–354.

Baker, D.F. 1979. *Geology and Geochemistry of an Alkali Volcanic Suite (Skinner Cove Formation) in the Humber Arm Allochthon, Newfoundland*. Memorial University of Newfoundland.

Batten Hender, K.L. and Dix, G.R. 2008. Facies development of a Late Ordovician mixed carbonate-siliciclastic ramp proximal to the developing Taconic orogen: Lourdes Formation, Newfoundland, Canada. *Facies*, **54**, 121–149, https://doi.org/10.1007/s10347-007-0126-0.

Bazinet, J.P. 1980. *Geology of the Gander Group, Gander River Ultramafic Belt and Davidsville Group in the Johnatan's Pond-Weir's Pond Area, Northeast Newfoundland* . Brock University.

Bergström, S.M., Riva, J. and Kay, M. 1974. Significance of Conodonts, Graptolites, and Shelly Faunas from the Ordovician of Western and North-Central Newfoundland. *Canadian Journal of Earth Sciences*, **11**, 1625–1660.

Blackwood, R.F. 1977. Northeastern Gander Zone, Newfoundland. *In*: *Report of Activities for 1977: Newfoundland Department of Mines and Energy Report 78-1*. 72–79.

Boschman, L.M., van Hinsbergen, D.J.J., Torsvik, T.H., Spakman, W. and Pindell, J.L. 2014. Kinematic reconstruction of the Caribbean region since the Early Jurassic. *Earth-Science Reviews*, **138**, 102–136, https://doi.org/10.1016/j.earscirev.2014.08.007.

Boschman, L.M., van Hinsbergen, D.J.J. and Spakman, W. 2021. Reconstructing Jurassic-Cretaceous Intra-Oceanic Subduction Evolution in the Northwestern Panthalassa Ocean Using Ocean Plate Stratigraphy From Hokkaido, Japan. *Tectonics*, **40**, https://doi.org/10.1029/2019TC005673.

Bostock, H.H. 1988. Geology and petrochemistry of the Ordovician volcano-plutonic Robert's Arm Group, Notre Dame Bay, Newfoundland. *Energy, Mines and Resources Canada, Geological Survey of Canada*.

Boyce, W.D., Ash, J.S. and Dickson, W.L. 1993. The significance of a new bivalve fauna from the Gander map area (2D/15) and a review of Silurian bivalve-bearing faunas in central Newfoundland. *Current Research*, **93**, 187–194.

Brem, A.G., Lin, S., Van Staal, C.R., Davis, D.W. and McNicoll, V.J. 2007. The Middle Ordovician to Early Silurian voyage of the Dashwoods microcontinent, West Newfoundland; based on new U/Pb and 40Ar/39Ar geochronological and kinematic constraints. *American Journal of Science*, **307**, 311–338, https://doi.org/10.2475/02.2007.01.

Brown, M. 2007. Metamorphic Conditions in Orogenic Belts: A Record of Secular Change. *International Geology Review*, **49**, 193–234.

Burgess, J.L., Brown, M., Dallmeyer, R.D. and van Staal, C.R. 1995. Microstructure, metamorphism, thermochronology and P-T-t-deformation history of the Port aux Basques gneisses, south-west Newfoundland, Canada. *Journal of Metamorphic Geology*, **13**, 751–776, https://doi.org/10.1111/j.1525-1314.1995.tb00257.x.

Casey, J.F. and Karson, J.A. 1981. Magma chamber profiles from the Bay of Islands ophiolite complex. *Nature*, **292**, 295–301.

Casey, J.F. and Kidd, W.S.F. 1981. A parallochthonous group of sedimentary rocks unconformably overlying the Bay of Islands ophiolite complex, North Arm Mountain, Newfoundland. *Canadian Journal of Earth Sciences*, **18**, 1035–1050.

Casey, J.F., Karson, J.A., Elthon, D., Rosencrantz, E. and Titus, M. 1983. Reconstruction of the geometry of accretion during formation of the Bay of Islands ophiolite complex. *Tectonics*, **2**, 509–528.

Casey, J.F., Elthon, D.L., Siroky, F.X., Karson, J.A. and Sullivan, J. 1985. Geochemical and geological evidence bearing on the origin of the Bay of Islands and Coastal Complex Ophiolites of Western Newfoundland. *Tectonophysics*, **116**, 1–40.

Castonguay, S., van Staal, C.R., Joyce, N., Skulski, T. and Hibbard, J.P. 2014. Taconic metamorphism preserved in the Baie Verte peninsula, Newfoundland Appalachians: Geochronological evidence for ophiolite obduction and subduction and exhumation of the leading edge of the Laurentian (Humber) margin during closure of the Taconic Seaway. *Geoscience Canada*, **41**, 459–482, https://doi.org/10.12789/geocanj.2014.41.055.

Cawood, P.A. 1982. Structural relations in the subduction complex of the Paleozoic New England fold belt, Eastern Australia. *Journal of Geology*, **90**, 381–392.

Cawood, P.A. and Nemchin, A.A. 2001. Paleogeographic development of the east Laurentian margin: Constraints from U-Pb dating of detrital zircons in the Newfoundland Appalachians. *Geological Society of America Bulletin*, **113**, 1234–1246.

Cawood, P.A. and Suhr, G. 1992. Generation and obduction of ophiolites: Constraints from the Bay of Islands Complex, western Newfoundland. *Tectonics*, **11**, 884–897, https://doi.org/10.1029/92TC00471.

Cawood, P.A., van Gool, J.A. and Dunning, G.R. 1996. Geological development of eastern Humber and western Dunnage zones: Corner Brook - Glover Island region, Newfoundland. *Canadian Journal of Earth Sciences*, **33**, 182–198.

Cawood, P.A., Mccausland, P.J.A. and Dunning, G.R. 2001. Opening Iapetus: Constraints from the Laurentian margin in Newfoundland. *Geological Society of America Bulletin*, **113**, 443–453.

Cawood, P.A., Kröner, A., Collins, W.J., Kusky, T.M., Mooney, W.D. and Windley, B.F. 2009. Accretionary orogens through Earth history. *Geological Society Special Publication*, **318**, 1–36, https://doi.org/10.1144/SP318.1.

Cawood, P.A., Merdith, A.S. and Murphy, J.B. 2024. Syn-emplacement ophiolites and relationship to supercontinent cycle. *Earth and Planetary Science Letters*, **641**, https://doi.org/10.1016/j.epsl.2024.118810.

Chandler, F.W., Sullivan, R.W. and Currie, K.L. 1987. The age of the Springdale Group, western Newfoundland, and correlative rocks-evidence for a Llandovery overlap assemblage in the Canadian Appalachians. *Transactions of the Royal Society of Edinburgh: Earth Sciences*, **78**, 41–49.

Colman-Sadd, S.D. 1980. Geology of south-central Newfoundland and evolution of the eastern margin of Iapetus. *American Journal of Science*, **280**, 991–1017.

Colman-Sadd, S.D. and Swinden, H.S. 1982. Geology and mineral potential of southcentral Newfoundland. *Newfoundland Department of Mines and Energy. Geological Survey Branch Report*, **82–8**, 102.

Colman-Sadd, S.P. and Swinden, H.S. 1984. A tectonic window in central Newfoundland? Geological evidence that the Appalachian Dunnage Zone may be allochthonous. *Canadian Journal of Earth Sciences*, **21**, 1349–1367.

Colman-Sadd, S.P., Dunning, G.R. and Dec, T. 1992. Dunnage-Gander relationships and Ordovician orogeny in central Newfoundland; a sediment provenance and U/Pb age study. *American Journal of Science*, **292**, 317–355.

Colman-Sadd, S.P., Hayes, J.P. and Knight, I. 2000. Geology of the Island of Newfoundland (digital version of Map 90-01 with minor revisions). *Newfoundland Department of Mines and Energy, Geological Survey, Map 2000-30, scale 1:1 000 000*.

Conliffe, J. and Hamilton, M. 2022. Geology and geochronology of the Grand Lake Ophiolite Complex and its overlying cover rocks in western Newfoundland: evidence for early fore-arc magmatism in the Baie Verte Oceanic Tract. *Geological Association of Canada/ Mineralogical Association of Canada, Halifax, Nova Scotia*.

Conliffe, J., Archibald, D.B. and Sparkes, B.A. 2024. Lithium-Cesium-Tantalum (LCT) pegmatites in southwestern Newfoundland. *Current Research*, **24**, 31–52.

Coombs, A.M., Zagorevski, A., McNicoll, V. and Hanchar, J.M. 2012. Preservation of terranes during the assembly of the Annieopsquotch Accretionary Tract: Inferences from the provenance of a Middle Ordovician ophiolite to arc transition, central Newfoundland Appalachians. *Canadian Journal of Earth Sciences*, **49**, 128–146, https://doi.org/10.1139/E11-042.

Coyle, M. and Strong, D.F. 1986. Geology of the Springdale Group: a newly recognized Silurian epicontinental-type caldera in Newfoundland. *Canadian Journal of Earth Sciences*, **24**, 1135–1148.

Currie, K.L. 1995. The northeastern end of the Dunnage Zone in Newfoundland. *Atlantic Geology*, **31**, 25–38.

Currie, K.L. 1997. Geology, Gander River - Gander Bay Region, Newfoundland (2E east half). *Geological Survey of Canada, Open File 3467, scale 1:100000*.

Currie, K.L., Van Breeman, O., Hunt, P.A. and Van Berkel, J.T. 1992. Age of high-grade gneisses south of Grand Lake. *Atlantic Geology*, **28**, 153–161.

Dallmeyer, R.D. 1977. Diachronous ophiolite obduction in Western Newfoundland: evidence from 40Ar/39Ar ages of the Hare Bay metamorphic aureole. *American Journal of Science*, **277**, 61–72.

de Wit, M.J. and Armstrong, R. 2014. Ode to field geology of Williams: Fleur de lys nectar still fermenting on belle isle. *Geoscience Canada*, **41**, 118–137, https://doi.org/10.12789/geocanj.2014.41.043.

Dean, W.T. 1985. Relationships of Cambrian–Ordovician faunas in the Caledonide-Appalachian Region, with particular reference to trilobites. *The Tectonic Evolution of the Caledonide-Appalachian Orogen, International Monograph Series on Interdisciplinary Earth Science Research and Applications. Friedrich Vieweg and Sohn, Braunschweig, Germany*, 16–47.

Dec, T. and Colman-Sadd, S. 1990. Timing of ophiolite emplacement onto the Gander zone: evidence from provenance studies in the Mount Cormack Subzone. *Current Research*, **90**, 289–303.

Dickson, W. 2006. THE SILURIAN INDIAN ISLANDS GROUP AND ITS RELATIONSHIPS TO ADJACENT UNITS. *Current Research*, 1–24.

Dickson, W.L., McNicoll, V.J., Nowlan, G.S. and Dunning, G.R. 2007. The Indian Islands Group and its relationships to adjacent units: recent data. *Current Research*, **07–1**, 1–9.

D'Lemos, R.S., Schofield, D.I., Holdsworth, R.E. and King, T.R. 1997. Deep crustal and local rheological controls on the siting and reactivation of fault and shear zones, northeastern Newfoundland. *Journal of the Geological Society*, **154**, 117–121.

Domeier, M. 2016. A plate tectonic scenario for the Iapetus and Rheic oceans. *Gondwana Research*, **36**, 275–295, https://doi.org/10.1016/j.gr.2015.08.003.

Dubé, B., Dunning, G. and Lauzière, K. 1995. Geology of the Hope Brook Mine, Newfoundland, Canada: A Preserved Late Proterozoic High-Sulfidation Epithermal Gold Deposit and Its Implications for Exploration. *Economic Geology*, **93**, 405–436.

Dubé, B., Dunning, G.R., Lauzière, K. and Roddick, J.C. 1996. New insights into the Appalachian Orogen from geology and geochronology along the Cape Ray fault zone, southwest Newfoundland. *Geological Society of America Bulletin*, **108**, 101–116.

Dunning, G.R. 1981. The Annieopsquotch Ophiolite Belt, southwest Newfoundland. *Current Research*, **81**, 11–15.

Dunning, G.R. 1987b. U/Pb geochronology of the Coney Head Complex, Newfoundland. *Canadian Journal of Earth Sciences*, **24**, 1072–1075.

Dunning, G.R. and Chorlton, L.B. 1985. The Annieopsquotch ophiolite belt of southwest Newfoundland: Geology and tectonic significance. *Geological Society of America Bulletin*, **96**, 1466–1476.

Dunning, G.R. and Krogh, T.E. 1985. Geochronology of ophiolites of the Newfoundland Appalachians. *Canadian Journal of Earth Sciences*, **22**, 1659–1670.

Dunning, G.R. and O'Brien, S.J. 1989. Late Proterozoic-early Paleozoic crust in the Hermitage flexure, Newfoundland Appalachians: U/Pb ages and tectonic significance. *Geology*, **17**, 548–551.

Dunning, G.R., Kean, B.F., Thurlow, J.G. and Swinden, H.S. 1987a. Geochronology of the Buchans, Roberts Arm, and Victoria Lake groups and Mansfield Cove Complex, Newfoundland (Canada). *Canadian Journal of Earth Sciences*, **24**, 1175–1184, https://doi.org/10.1139/e87-113.

Dunning, G.R., O'Brien, S.J., Colman-Sadd, S.P., Blackwood, R.F., Dickson, W.L., O'Neill, P.P. and Krogh, T.E. 1990. Silurian orogeny in the Newfoundland Appalachians. *Journal of Geology*, **98**, 895–913.

Elliott, C.G., Barnes, C.R. and Williams, P.F. 1989. Southwest New World Island stratigraphy: new fossil data, new implications for the history of the Central Mobile Belt, Newfoundland. *Canadian Journal of Earth Sciences*, **26**, 2062–2074, https://doi.org/10.1139/e89-173.

Elliott, C.G., Dunning, G.R. and Williams, P.F. 1991. New U/Pb zircon age constraints on the timing of deformation in north-central Newfoundland and implications for early Paleozoic Appalachian orogenesis. *Geological Society of America Bulletin*, **103**, 125–135, https://doi.org/10.1130/0016-7606(1991)103<0125:NUPZAC>2.3.CO;2.

Elthon, D. 1991. Geochemical evidence for formation of the Bay of Islands ophiolite above a subduction zone. *Nature*, **354**, 140–143.

Evans, D.T.W. and Kean, B.F. 2002. *The Victoria Lake Supergroup, Central Newfoundland-Its Definition, Setting and Volcanogenic Massive Sulphide Mineralization*.

Evans, D.T.W., Kean, B.F. and Dunning, G.R. 1990. Geological studies, Victoria Lake Group, Central Newfoundland. *Current Research*, **90**, 131–144.

Fletchers, T.P. 2006. Bedrock geology of the Cape St. Mary's Peninsula, southwest Avalon Peninsula, Newfoundland. *Government of Newfoundland and Labrador, Geological Survey, Department of Natural Resources, St. John's, Report*, **06–02**, 117.

Fournier-Roy, F., Guilmette, C., Larson, K., Godet, A., Soret, M., van Staal, C.R. and Bédard, J.H. 2024. Geochemistry and geochronology of the Bay of Islands metamorphic sole, Newfoundland, Canada: Protoliths and implications for subduction initiation. *Bulletin of the Geological Society of America*, **136**, 371–387, https://doi.org/10.1130/B36662.1.

Gasser, D., Majka, J., Jakob, J. and Barnes, C.J. 2024. A review of the Caledonian Wilson cycle from a North Atlantic perspective. *Journal of the Geological Society*, **181**.

Gill, J.B. 1981. *Orogenic Andesites and Plate Tectonics*.

Goodwin, L.B. and Williams, P.F. 1996. Deformation path partitioning within a transpressive shear zone, Marble Cove, Newfoundland. *Journal of Structural Geology*, **18**, 975–990, https://doi.org/10.1016/0191-8141(96)00015-6.

Gradstein, F.M. and Ogg, J.G. 2020. The Chronostratigraphic Scale. *In*: *Geologic Time Scale 2020*. 21–32., https://doi.org/10.1016/B978-0-12-824360-2.00002-4.

Graham, B., Dunning, G. and Leitch, A.M. 2021. Magma Mushes of the Fogo Island Batholith: a Study of Magmatic Processes at Multiple Scales. *Journal of Petrology*, **61**, https://doi.org/10.1093/petrology/egaa097.

Guilmette, C., Smit, M.A., et al. 2018. Forced subduction initiation recorded in the sole and crust of the Semail Ophiolite of Oman. *Nature Geoscience*, **11**, 688–695, https://doi.org/10.1038/s41561-018-0209-2.

Guilmette, C., van Hinsbergen, D.J.J., et al. 2023. Formation of the Xigaze Metamorphic Sole under Tibetan continental lithosphere reveals generic characteristics of subduction initiation. *Communications Earth and Environment*, **4**, https://doi.org/10.1038/s43247-023-01007-w.

Hacker, B.R. and Gnos, E. 1997. The conundrum of Samail: explaining the metamorphic history. *Tectonophysics*, **279**, 215–226.

Handy, M.R., Schmid, S.M., Bousquet, R., Kissling, E. and Bernoulli, D. 2010. Reconciling plate-tectonic reconstructions of Alpine Tethys with the geological-geophysical record of spreading and subduction in the Alps. *Earth-Science Reviews*, **102**, 121–158, https://doi.org/10.1016/j.earscirev.2010.06.002.

Harper, D.A.T., Owen, A.W. and Bruton, D.L. 2009. Ordovician life around the Celtic fringes: Diversifications, extinctions and migrations of brachiopod and trilobite faunas at middle latitudes. *Geological Society Special Publication*, **325**, 157–170, https://doi.org/10.1144/SP325.8.

Hashmi, S. 2023. Humus as a sample medium to target Au mineralization in Newfoundland: preliminary data from Glover Island (NTS 12A/12 AND 13), Jackson's Arm (NTS 12H/15) and Nippers Harbour (NTS 2E/13) map areas. *Current Research*, **23–1**, 1–21.

Heaman, L.M., Erdmer, P. and Owen, J. V. 2002. U-Pb geochronologic constraints on the crustal evolution of the Long Range Inlier, Newfoundland. *Canadian Journal of Earth Sciences*, **39**, 845–865, https://doi.org/10.1139/e02-015.

Hibbard, J.P. 1983. Geology of the Baie Verte Peninsula, Newfoundland. *Mineral Development Division Department of Mines and Energy, Government of Newfoundland and Labrador Memoir*, **2**.

Hibbard, J.P., Stouge, S. and Skevington, D. 1977. Fossils from the Dunnage Mélange, north-central Newfoundland. *Canadian Journal of Earth Sciences*, **14**, 1176–1178, https://doi.org/10.1139/e77-107.

Hibbard, J.P., van Staal, C.R., Rankin, D.W. and Williams, H. 2006. Lithotectonic map of the Appalachian Orogen, Canada-United States of America (North sheet). *Geological Survey of Canada, Map 2096A, scale 1:1 500 000.*

Hibbard, J.P., van Staal, C.R. and Rankin, D.W. 2007. A comparative analysis of pre-Silurian crustal building blocks of the northern and the southern Appalachian orogen. *American Journal of Science*, **307**, 23–45, https://doi.org/10.2475/01.2007.02.

Hinchey, J.G. and McNicoll, V. 2009. Tectonostratigraphic architecture and VMS mineralization of the southern Tulks Volcanic Belt: new insights from U-Pb geochronology and lithogeochemistry. *Current Research*, 13–42.

Hiscott, R.N. 1984. Ophiolitic source rocks for Taconic-age flysch: Trace-element evidence. *Geological Society of America Bulletin*, **95**, 1261–1267.

Hodgin, E.B., Macdonald, F.A., Karabinos, P., Crowley, J.L. and Reusch, D.N. 2022. A reevaluation of the tectonic history of the Dashwoods terrane using in situ and isotope-dilution U-Pb geochronology, western Newfoundland. *In*: *Special Paper of the Geological Society of America*. 243–264., https://doi.org/10.1130/2021.2554(10).

Hodych, J.P., Cox, R.A. and Košler, J. 2004. An equatorial Laurentia at 550 Ma confirmed by Grenvillian inherited zircons dated by LAM ICP-MS in the Skinner Cove volcanics of western Newfoundland: Implications for inertial interchange true polar wander. *Precambrian Research*, **129**, 93–113, https://doi.org/10.1016/j.precamres.2003.10.012.

Hoffman, P.F. 1988. United Plates of America, The Birth of a Craton: Early Proterozoic Assembly and Growth of Laurentia. *Annual Review of Earth and Planetary Sciences*, **16**, 543–603.

Holdsworth, R.E. 1994. Structural evolution of the Gander-Avalon terrane boundary: a reactivated transpression zone in the NE Newfoundland Appalachians. *Journal of the Geological Society*, **151**, 629–646.

Honsberger, I.W., Sandeman, H.A.I., Bleeker, W. and Kamo, S.L. 2023. Gabbro intrusions along the Dog Bay Line-Appleton fault zone gold corridor, northeast-central Newfoundland: U-Pb baddeleyite geochronology and lithogeochemistry. *Current Research*, **23**, 31–46.

Horne, G.S. 1970. Complex volcanic-sedimentary patterns in the Magog Belt of Northeastern Newfoundland. *Geological Society of America Bulletin*, **81**, 1767–1788.

Isozaki, Y., Maruyama, Y. and Furuoka, S. 1990. Accreted oceanic materials in Japan. *Tectonophysics*, **181**, 179–205.

Jacobi, R.D. and Wasowski, J.J. 1985. Geochemistry and plate-tectonic significance of the volcanic rocks of the Summerford Group, north-central Newfoundland. *Geology*, **13**, 126–130.

James, N.P. and Stevens, R.K. 1986. Stratigraphy and correlation of the Cambro-Ordovician Cow Head Group, western Newfoundland. *Geological Survey of Canada*.

Jamieson, R.A. 1981. Metamorphism during Ophiolite Emplacement-the Petrology of the St. Anthony Complex. *Journal of Petrology*, **22**, 397–449.

Jamieson, R.A. 1988. Metamorphic P-T-t data from Western Newfoundland and Cape Breton; implications for Taconian and Acadian tectonics. *In*: *Program with Abstracts-Geological Association of Canada; Mineralogical Association of Canada: Joint Annual Meeting*.

Jenner, G.A. and Swinden, H.S. 1993. The Pipestone Pond Complex, central Newfoundland: complex magmatism in an eastern Dunnage Zone ophiolite. *Canadian Journal of Earth Sciences*, **30**, 434–448, https://doi.org/10.1139/e93-032.

Jenner, G.A., Dunning, G.R., Malpas, J., Brown, M. and Brace, T. 1991. Bay of Islands and Little Port complexes, revisited: age, geochemical and isotopic evidence confirm suprasubduction-zone origin. *Canadian Journal of Earth Sciences*, **28**, 1635–1652.

Johnston, D.H., Williams, H. and Currie, K.L. 1994. The Noggin Cove Formation: a Middle Ordovician back-arc basin deposit in northeastern Newfoundland. *Atlantic Geology*, **30**, 183–194.

Kamo, S.L., Gower, C.F. and Krogh, T.E. 1989. Birthdate for the Iapetus Ocean? A precise U-Pb zircon and baddeleyite age for the Long Range dikes, southeast Labrador. *Geology*, **17**, 602–605.

Karig, D.E. 1971. Origin and development of marginal basins in the western Pacific. *Journal of Geophysical Research*, **76**, 2542–2561, https://doi.org/10.1029/jb076i011p02542.

Karson, J. and Dewey, J.F. 1978. Coastal Complex, western Newfoundland: An Early Ordovician oceanic fracture zone. *Geological Society of America Bulletin*, **89**, 1037–1049.

Karson, J.A., Elthon, D.L. and Delong, S.E. 1983. Ultramafic intrusions in the Lewis Hills Massif, Bay of Islands Ophiolite Complex, Newfoundland: Implications for igneous processes at oceanic fracture zones. *Geological Society of America Bulletin*, **94**, 15–29.

Kay, M. 1976. Dunnage Melange and Subduction of the Protacadic Ocean, northeast Newfoundland. *Special Paper of the Geological Society of America*, **175**, 1–51, https://doi.org/10.1130/SPE175-p1.

Kean, B.F., Evans, D.T.W. and Jenner, G.A. 1995. Geology and mineralization of the Lushs Bight Group. *Government of Newfoundland and Labrador, Department of Mines and Energy, Geological Survey*, **95**.

Keen, C.E., Keen, M.J., et al. 1986. Deep seismic reflection profile across the northern Appalachians. *Geology*, **14**, 141–145.

Kellett, D.A., Warren, C., Larson, K.P., Zwingmann, H., van Staal, C.R. and Rogers, N. 2016. Influence of deformation and fluids on Ar retention in white mica: Dating the Dover Fault, Newfoundland Appalachians. *Lithos*, **254–255**, 1–17, https://doi.org/10.1016/j.lithos.2016.03.003.

Kerr, A. 1997. Space-time composition relationships among Appalachian-cycle plutonic suites in Newfoundland. *In*: Sinha, A. K., Whalen, J. B. and Hogan, J. P. (eds) *The Nature of Magmatism in the Appalachian Orogen: Geological Society of America Memoir*. 193–220., https://doi.org/10.1130/0-8137-1191-6.193.

Kerr, A. 2019. Classic rock tours 2. Exploring a famous ophiolite: A guide to the bay of Islands igneous complex in gros morne national park, Western Newfoundland, Canada. *Geoscience Canada*, **46**, 101–136, https://doi.org/10.12789/geocanj.2019.46.149.

Kerr, A. and Knight, I. 2004. Preliminary report on the stratigraphy and structure of Cambrian and Ordovician rocks in the Coney Arm area, western White Bay (NTS map area 12H/15). *Current Research*, **04–1**, 127–156.

Kerr, A., Dunning, G.R. and Tucker, R.D. 1993. The youngest Paleozoic plutonism of the Newfoundland Appalachians: U–Pb ages from the St. Lawrence and François granites. *Canadian Journal of Earth Sciences*, **30**, 2328–2333, https://doi.org/10.1139/e93-202.

Kimura, G. 1996. Collision orogeny at arc-arc junctions in the Japanese Islands. *Island Arc*, **5**, 262–275, https://doi.org/10.1111/j.1440-1738.1996.tb00031.x.

Knight, I., James, N.P. and Lane, T.E. 1991. The Ordovician St. George Unconformity, northern Appalachians: The relationship of plate convergence at the St. Lawrence Promontory to the Sauk/Tippecanoe sequence boundary. *Geological Society of America Bulletin*, **103**, 1200–1225.

Kotowski, A.J., Cisneros, M., Behr, W.M., Stockli, D.F., Soukis, K., Barnes, J.D. and Ortega-Arroyo, D. 2022. Subduction, Underplating, and Return Flow Recorded in the Cycladic Blueschist Unit Exposed on Syros, Greece. *Tectonics*, **41**, https://doi.org/10.1029/2020TC006528.

Kröner, A. 2010. The role of geochronology in understanding continental evolution. *Geological Society Special Publication*, **338**, 179–196, https://doi.org/10.1144/SP338.9.

Lacombe, R.A., Waldron, J.W.F., Williams, S.H. and Harris, N.B. 2019. Mélanges and disrupted rocks at the leading edge of the Humber Arm Allochthon, W. Newfoundland Appalachians: Deformation under high fluid pressure. *Gondwana Research*, **74**, 216–236, https://doi.org/10.1016/j.gr.2019.03.002.

Landing, E. 1996. Avalon-Insular continent by the latest Precambrian. *In*: *Avalonia and Related Peri-Gondwanan Terranes of the Circum-North Atlantic: Boulder, Colorado, Geological Society of America Special Paper 304*.

Landing, E., Keppie, J.D., Keppie, D.F., Geyer, G. and Westrop, S.R. 2022. Greater Avalonia—latest Ediacaran–Ordovician "peribaltic" terrane bounded by continental margin prisms ("Ganderia," Harlech Dome, Meguma): Review, tectonic implications, and paleogeography. *Earth-Science Reviews*, **224**, https://doi.org/10.1016/j.earscirev.2021.103863.

Landing, E., Schmitz, M.D., Westrop, S.R. and Geyer, G. 2023. U-Pb zircon dates from North American and British Avalonia bracket the Lower-Middle Cambrian boundary interval, with evaluation of the Miaolingian Series as a global unit. *Geological Magazine*, **160**, 1790–1816, https://doi.org/10.1017/S0016756823000729.

Langille, A.E. 2012. *A Detailed Petrographic, Geochemical and Geochronological Study of the Hare Bay Gneiss, Northeastern Newfoundland*. Memorial University of Newfoundland.

Lee, C.B. 1994. *Polykinematic Evolution of the Teakettle and Carmanville Mélanges in the Exploits Subzone, Northeast Newfoundland*. Memorial University of Newfoundland.

Lin, S., van Staal, C.R. and Dubé, B. 1994. Promontory-promontory collision in the Canadian Appalachians. *Geology*, **22**, 897–900.

Lin, S., Brem, A.G., van Staal, C.R., Davis, D.W., McNicoll, V.J. and Pehrsson, S. 2013. The Corner Brook Lake block in the Newfoundland Appalachians: A suspect terrane along the Laurentian margin and evidence for large-scale orogen-parallel motion. *Bulletin of the Geological Society of America*, **125**, 1618–1632, https://doi.org/10.1130/B30805.1.

Lindholm, R.M. and Casey, J.F. 1989. Regional significance of the Blow Me Down Brook Formation, western Newfoundland: New fossil evidence for an Early Cambrian age. *Geological Society of America Bulletin*, **101**, 1–13.

Lissenberg, C.J. and Van Staal, C.R. 2002. The relationships between the Annieopsquotch Ophiolite Belt, the Dashwoods block and the Notre Dame Arc in southwestern Newfoundland. *Current Research*, 145–153.

Lissenberg, C.J., Zagorevski, A., Mcnicoll, V.J., Van Staal, C.R. and Whalen, J.B. 2005a. Assembly of the Annieopsquotch Accretionary Tract, Newfoundland Appalachians: Age and Geodynamic Constraints from Syn-Kinematic Intrusions. *Journal of Geology*, **113**, 553–570.

Lissenberg, C.J., van Staal, C.R., Bédard, J.H. and Zagorevski, A. 2005b. Geochemical constraints on the origin of the Annieopsquotch ophiolite belt, Newfoundland Appalachians. *Bulletin of the Geological Society of America*, **117**, 1413–1426, https://doi.org/10.1130/B25731.1.

Lissenberg, C.J., McNicoll, V.J. and van Staal, C.R. 2006. The origin of mafic-ultramafic bodies within the northern Dashwoods Subzone, Newfoundland Appalachians The origin of mafic-ultramafic bodies within the northern Dashwoods Subzone, Newfoundland Appalachians. *Atlantic Geology*, **42**, 1–12.

Lynch, E.P., Feely, M. and Wilton, D.H.C. 2009. New constraints on the timing of molybdenite mineralization in the Devonian Ackley Granite Suite, southeastern Newfoundland: preliminary results of Re-Os geochronology. *Current Research*, **09**, 225–234.

MacLachlan, K. and Dunning, G. 1998a. U-Pb ages and tectono-magmatic evolution of Middle Ordovician volcanic rocks of the Wild Bight Group, Newfoundland Appalachians. *Canadian Journal of Earth Sciences*, **35**, 998–1017.

MacLachlan, K. and Dunning, G. 1998b. U-Pb ages and tectonomagmatic relationships of early Ordovician low-Ti tholeiites, boninites and related plutonic rocks in central Newfoundland, Canada. *Contrib. Mineral. Petrol.*, **133**, 235–258.

MacLachlan, K., O'Brien, B.H. and Dunning, G.R. 2001. Redefinition of the Wild Bight Group, Newfoundland: Implications for models of island-arc evolution in the Exploits Subzone. *Canadian Journal of Earth Sciences*, **38**, 889–907, https://doi.org/10.1139/cjes-38-6-889.

McCausland, P.J.A., Hodych, J.P. and Dunning, G.R. 1997. Evidence from Western Newfoundland for the final breakup of Rodinia. *U-Pb age and paleolatitude of the Skinner Cove Volcanics: Geological Association of Canada 1997 Annual Meeting, Abstract Volume*, A-99.

McNicoll, V.J., Squires, G.C., Wardle, R.J., Dunning, G.R. and O'Brien, B.H. 2006. U-Pb geochronological evidence for Devonian deformation and gold mineralization in the eastern Dunnage zone, Newfoundland. *Current Research*, **06**, 45–60.

McNicoll, V.J., Squires, G.C., Kerr, A. and Moore, P.J. 2008. Geological and metallogenic implications of U-Pb zircon geochronological data from the Tally Pond area, central Newfoundland. *Current Research*, 173–192.

Merdith, A.S., Williams, S.E., et al. 2021. Extending full-plate tectonic models into deep time: Linking the Neoproterozoic and the Phanerozoic. *Earth-Science Reviews*, **214**, https://doi.org/10.1016/j.earscirev.2020.103477.

Nance, R.D., Murphy, J.B. and Keppie, J.D. 2002. A Cordilleran model for the evolution of Avalonia. *Tectonophysics*, **352**, 11–31.

Nance, R.D., Murphy, J.B., et al. 2008. Neoproterozoic-early Palaeozoic tectonostratigraphy and palaeogeography of the peri-Gondwanan terranes: Amazonian v. West African connections. *Geological Society Special Publication*, **297**, 345–383, https://doi.org/10.1144/SP297.17.

Neuman, R.B. 1984. Geology and paleobiology of islands in the Ordovician Iapetus Ocean: Review and implications. *Geological Society of America Bulletin*, **95**, 1188–1201.

Nowlan, G.S. and Thurlow, J.G. 1984. Middle Ordovician conodonts from the Buchans Group, central Newfoundland, and their significance for regional stratigraphy of the Central Volcanic Belt. *Canadian Journal of Earth Sciences*, **21**, 284–296.

O'Brien, B.H. and O'Brien, S.J. 1990. Re-investigation and re-interpretation of the Silurian La Poile Group of Southwestern Newfoundland. *Current Research*, **90**, 305–316.

O'Brien, B.H., O'Brien, S.J. and Dunning, G.R. 1991. Silurian cover, Late Precambrian-Early Ordovician basement, and the chronology of the Silurian orogenesis in the Hermitage Flexure (Newfoundland Appalachians). *American Journal of Science*, **291**, 760–799.

O'Brien, B.H., O'Brien, S.J., Dunning, G.R. and Tucker, R.D. 1993. Episodic reactivation of a Late Precambrian mylonite zone on the Gondwanan Margin of the Appalachians, southern Newfoundland. *Tectonics*, **12**, 1043–1055, https://doi.org/10.1029/93TC00110.

O'Brien, B.H., Swinden, H.S., Dunning, G.R., Williams, S.H. and O'Brien. F.H. 1997. A peri-Gondwanan arc-back arc complex in Iapetus: Early-Mid Ordovician evolution of the Exploits Group, Newfoundland. *American Journal of Science*, **297**, 220–272.

O'Brien, S.J. and King, A.F. 2005. Late Neoproterozoic (Ediacaran) stratigraphy of Avalon Zone sedimentary rocks, Bonavista Peninsula, Newfoundland. *Current Research*, 101–113.

O'Brien, S.J., Wardle, R.J. and King, A.F. 1983. The Avalon Zone: A Pan-African terrane in the Appalachian Orogen of Canada. *Geological Journal*, **18**, 195–222.

O'Brien, S.J., O'Brien, B.H., Dunning, G.R. and Tucker, R.D. 1996. Late Neoproterozoic Avalonian and related peri-Gondwanan rocks of the Newfoundland Appalachians. *Geological Society of America Special Paper*.

O'Neill, P.P. 1990. Geology of the northeast Gander Lake map area (NTS 2D/15) and the northwest Gambo map area (NTS 2D/16). *Current Research*, 317–326.

O'Neill, P.P. 1991. Geology of the Weir's Pond area, Newfoundland (NTS 2El1). *Geological Survey Branch, Department of Mines and Energy, Government of Newfoundland and Labrador*.

O'Neill, P.P. 1992. Geology of the northwestern part of the Glovertown map area (NTS 2D/9) and the northeastern part of the Dead Wolf Pond map area (NTS 2D/10). *Current Research*, 195–202.

O'Neill, P.P. and Blackwood, F. 1989. A proposal for revised stratigraphic nomenclature of the Gander and Davidsville groups and the Gander River Ultrabasic Belt, of northeastern Newfoundland. *Current Research*, **89**, 127–130.

Owen, J.V. 1991. Significance of epidote in orbicular diorite from the Grenville Front zone, eastern Labrador. *Mineralogical Magazine*, **55**, 173–181.

Pearce, J.A., Lippard, S.J. and Roberts, S. 1984. Characteristics and tectonic significance of supra-subduction zone ophiolites. *Geological Society, London, Special Paper*, **16**, 77–94.

Péron-Pinvidic, G. and Manatschal, G. 2010. From microcontinents to extensional allochthons: Witnesses of how continents rift and break apart. *Petroleum Geoscience*, **16**, 189–197, https://doi.org/10.1144/1354-079309-903.

Peters, T. and Mercolli, I. 1998. Extremely thin oceanic crust in the Proto-Indian Ocean: Evidence from the Masirah Ophiolite, Sultanate of Oman. *Journal of Geophysical Research: Solid Earth*, **103**, 677–689.

Philippon, M., Cornée, J.J., et al. 2020. Eocene intra-plate shortening responsible for the rise of a faunal pathway in the northeastern Caribbean realm. *PLoS One*, **15**, https://doi.org/10.1371/journal.pone.0241000.

Pohlner, J.E., Schmitt, A.K., Chamberlain, K.R., Davies, J.H.F.L., Hildenbrand, A. and Austermann, G. 2020. Multimethod U-Pb baddeleyite dating: Insights from the Spread Eagle Intrusive Complex and Cape St. Mary's sills, Newfoundland, Canada. *Geochronology*, **2**, 187–208, https://doi.org/10.5194/gchron-2-187-2020.

Pollock, J.C., Wilton, D.H.C., Van Staal, C.R. and Morrissey, K.D. 2007. U-Pb detrital zircon geochronological constraints on the Early Silurian collision of Ganderia and Laurentia along the Dog Bay Line: The terminal Iapetan suture in the Newfoundland Appalachians. *American Journal of Science*, **307**, 399–433, https://doi.org/10.2475/02.2007.04.

Pollock, J.C., Hibbard, J.P. and van Staal, C.R. 2011. A paleogeographical review of the peri-Gondwanan realm of the Appalachian orogen. *Canadian Journal of Earth Sciences*, **49**, 259–288.

Quinn, L., Williams, S.H., Harper, D.A.T. and Clarkson, E.N.K. 1999. Late Ordovician foreland basin fill: Long Point Group of onshore western Newfoundland. *Bulletin of Canadian Petroleum Geology*, **47**, 63–80.

Ramezani, J. 1992. *The Geology, Geochemistry and U-Pb Geochronology of the Stog'er Tight Gold Prospect, Baie Verte Peninsula, Newfoundland*. Memorial University of Newfoundland.

Ritcey, D.H., Wilson, M.R. and Dunning, G.R. 1995. Gold Mineralization in the Paleozoic Appalachian Orogen: Constraints from Geologic, U/Pb, and Stable Isotope Studies of the Hammer Down Prospect, Newfoundland. *Economic Geology*, **90**, 1955–1965.

Rogers, N. and Van Staal, C.R. 2002. Toward a Victoria Lake Supergroup: A provisional stratigraphic revision of the Red Indian to Victoria Lakes area, Central Newfoundland. *Current Research*, 185–195.

Rogers, N., van Staal, C.R., McNicoll, V.J., Pollock, J., Zagorevski, A. and Whalen, J.B. 2006. Neoproterozoic and Cambrian arc magmatism along the eastern margin of the Victoria Lake Supergroup: A remnant of Ganderian basement in central Newfoundland? *Precambrian Research*, **147**, 320–341, https://doi.org/10.1016/j.precamres.2006.01.025.

Sandeman, H., McNicoll, V.J. and Evans, D.T.W. 2012. U-Pb geochronology and lithogeochemistry of the host rocks to the Reid gold deposit, Exploits subzone-Mount Cormack subzone boundary area, central Newfoundland. *Current Research*, **12**, 85–102, https://doi.org/10.13140/RG.2.1.4623.7203.

Scorsolini, L.G., van Staal, C., Yakymchuk, C., Hanchar, J.M. and Dyer, S. 2025. Exhumation Mechanisms of High-Pressure Rocks With High-Temperature Overprinting: Insights From Eclogites of the Baie Verte Peninsula, Newfoundland. *Journal of Metamorphic Geology*, **43**, 497–521, https://doi.org/10.1111/jmg.12817.

Scotese, C.R. 2023. Ordovician plate tectonic and palaeogeographical maps. *Geological Society Special Publication*, **532**, 91–109, https://doi.org/10.1144/SP532-2022-311.

Şengör, A.M.C. 1990. Plate Tectonics and Orogenic Research after 25 Years: A Tethyan Perspective. *Earth-Science Reviews*, **27**, 1–201.

Shao, L., Cao, L., Qiao, P., Zhang, X., Li, Q. and van Hinsbergen, D.J.J. 2017. Cretaceous–Eocene provenance connections between the Palawan Continental Terrane and the northern South China Sea margin. *Earth and Planetary Science Letters*, **477**, 97–107, https://doi.org/10.1016/j.epsl.2017.08.019.

Skulski, T., Castonguay, S., et al. 2010. Tectonostratigraphy of the Baie Verte Oceanic Tract and its ophiolite cover sequence on the Baie Verte Peninsula. *Current Research*, 315–335.

Skulski, T., Castonguay, S., et al. 2017. Digital geoscience atlas of Baie Verte Peninsula, Newfoundland and Labrador. *Geological Survey of Canada Open File 7342*, 22, https://doi.org/10.4095/298754.

Slack, J.F., Swinden, H.S., Piercey, S.J., Ayuso, R.A., van Staal, C.R. and LeHuray, A.P. 2024. Lead isotopes in New England (USA) volcanogenic massive sulfide deposits: implications for metal sources and pre-accretionary tectonostratigraphic terranes. *Canadian Journal of Earth Sciences*, **61**, 329–354, https://doi.org/10.1139/cjes-2023-0058.

Stenzel, S.R., Knight, I. and James, N.P. 1990. Carbonate platform to foreland basin: revised stratigraphy of the Table Head Group (Middle Ordovician), western Newfoundland. *Canadian Journal of Earth Sciences*, **27**, 14–26.

Stern, R.J. 2002. Subduction zones. *Reviews of Geophysics*, **40**.

Stern, R.J. and Bloomer, S.H. 1992. Subduction zone infancy: Examples from the Eocene Izu-Bonin-Mariana and Jurassic California arcs. *Geological Society of America Bulletin*, **104**, 1621–1636.

Stevens, R.K. 1970. Cambro-Ordovician flysch sedimentation and tectonics in west Newfoundland and their possible bearing on a proto-Atlantic Ocean. *In*: *Flysch Sedimentology in North America*. 165–177.

Strowbridge, S., Indares, A., Dunning, G. and Wälle, M. 2022. A Tonian volcano-sedimentary succession in Newfoundland, eastern North America: A post-Grenvillian link to the Asgard Sea? *Geology*, **50**, 655–659, https://doi.org/10.1130/G49885.1.

Suhr, G. and Cawood, P.A. 1993. Structural history of ophiolite obduction, Bay of Islands, Newfoundland. *Geological Society of America Bulletin*, **105**, 399–410.

Suhr, G. and Cawood, P.A. 2001. Southeastern Lewis Hills (Bay of Islands Ophiolite): Geology of a deeply eroded, inside-corner, ridge-transform intersection. *Geological Society of America Bulletin*, **113**, 1025–1038.

Suhr, G. and Edwards, S.J. 2000. Contrasting mantle sequences exposed in the Lewis Hills massif: Evidence for the early, arc-related history of the Bay of Islands ophiolite. *In*: Dilek, Y., Moores, E. M., Elthon, D. and Nicolas, A. (eds) *Ophiolites and Oceanic Crust: New Insights from Field Studies and the Ocean Drilling Program*. 433–442.

Swanson-Hysell, N.L. and Macdonald, F.A. 2017. Tropical weathering of the Taconic orogeny as a driver for Ordovician cooling. *Geology*, **45**, 719–722, https://doi.org/10.1130/G38985.1.

Swinden, H.S., Jenner, G.A. and Szybinski, Z.A. 1997. Magmatic and tectonic evolution of the Cambrian-Ordovician Laurentian margin of Iapetus: Geochemical and isotopic constraints from the Notre Dame subzone, Newfoundland. *In*: *The Nature of Magmatism in the Appalachian Orogen*. 367–395.

Szybinski, Z.A. 1995. *Paleotectonic and Structural Setting of the Western Notre Dame Bay Area, Newfoundland Appalachians*. Memorial University of Newfoundland.

Taira, A. 2001. Tectonic Evolution of the Japanese Island Arc System. *Annual Review of Earth and Planetary Sciences*, **29**, 109–134, https://doi.org/10.1146/annurev.earth.29.1.109.

Tapster, S., Roberts, N.M.W., Petterson, M.G., Saunders, A.D. and Naden, J. 2014. From continent to intra-oceanic arc: Zircon xenocrysts record the crustal evolution of the Solomon island arc. *Geology*, **42**, 1087–1090, https://doi.org/10.1130/G36033.1.

Thurlow, J.G., Spencer, C.P., Boerner, D.E., Reed, L.E. and Wright, J.A. 1992. Geological interpretation of a high resolution reflection seismic survey at the Buchans mine, Newfoundland1. *Canadian Journal of Earth Sciences*, **29**, 2022–2037.

Todd, S.E., Pufahl, P.K., Murphy, J.B. and Taylor, K.G. 2019. Sedimentology and oceanography of Early Ordovician ironstone, Bell Island, Newfoundland: Ferruginous seawater and upwelling in the Rheic Ocean. *Sedimentary Geology*, **379**, 1–15, https://doi.org/10.1016/j.sedgeo.2018.10.007.

Torsvik, T.H. 1998. Palaeozoic palaeogeography: A North Atlantic viewpoint. *GFF*, **120**, 109–118, https://doi.org/10.1080/11035899801202109.

Tucholke, B.E., Sawyer, D.S. and Sibuet, J.C. 2007. Breakup of the Newfoundland–Iberia rift. *Geological Society, London, Special Publications*, **282**, 9–46.

Tucker, R.D., O'brien, S.J. and O'brien, B.H. 1994. Age and implications of Early Ordovician (Arenig) plutonism in the type area of the Bay du Nord Group, Dunnage Zone, southern Newfoundland Appalachians Introduction and regional geological framework. *Canadian Journal of Earth Sciences*, **31**, 351–357.

Valverde-Vaquero, P. and van Staal, C. 2001. Relationships between the Dunnage-Gander zones in the Victoria Lake-Peter Strides Pond area. *Current Research*, 1–9.

Valverde-Vaquero, P., Dunning, G.R. and van Staal, C.R. 2000. The Margaree orthogneiss: an Ordovician, peri-Gondwanan, mafic-felsic igneous complex in southwestern Newfoundland 1. *Canadian Journal of Earth Sciences*, **37**, 1691–1710.

Valverde-Vaquero, P., van Staal, C.R., McNicoll, V.J. and Dunning, G.R. 2006a. Mid-Late Ordovician magmatism and metamorphism along the Gander margin in central Newfoundland. *Journal of the Geological Society, London*, **163**, 347–362.

Valverde-Vaquero, P., Dunning, G.R. and O'Brien, S.J. 2006b. Polycyclic evolution of the Late Neoproterozoic basement in the Hermitage Flexure region (southwest Newfoundland Appalachians): New evidence from the Cinq-Cerf gneiss. *Precambrian Research*, **148**, 1–18, https://doi.org/10.1016/j.precamres.2006.03.001.

van de Lagemaat, S.H.A., Cao, L., Asis, J., Advokaat, E.L., Mason, P.R.D., Dekkers, M.J. and van Hinsbergen, D.J.J. 2024. Causes of Cretaceous subduction termination below South China and

Borneo: Was the Proto-South China Sea underlain by an oceanic plateau? *Geoscience Frontiers*, **15**, https://doi.org/10.1016/j.gsf.2023.101752.

van der Velden, A.J., van Staal, C.R. and Cook, F.A. 2004. Crustal structure, fossil subduction, and the tectonic evolution of the Newfoundland Appalachians: Evidence from a reprocessed seismic reflection survey. *Bulletin of the Geological Society of America*, **116**, 1485–1498, https://doi.org/10.1130/B25518.1.

van Hinsbergen, D.J.J. and Schmid, S.M. 2012. Map view restoration of Aegean–West Anatolian accretion and extension since the Eocene. *Tectonics*, **31**.

van Hinsbergen, D.J.J. and Schouten, T.L.A. 2021. Deciphering paleogeography from orogenic architecture: constructing orogens in a future supercontinent as thought experiment. *American Journal of Science*, **321**, 955–1031, https://doi.org/10.2475/06.2021.09.

van Hinsbergen, D.J.J., Vissers, R.L.M. and Spakman, W. 2014. Origin and consequences of western Mediterranean subduction, rollback, and slab segmentation. *Tectonics*, **33**, 393–419, https://doi.org/10.1002/2013TC003349.

van Hinsbergen, D.J.J., Peters, K., et al. 2015. Dynamics of intraoceanic subduction initiation: 2. suprasubduction zone ophiolite formation and metamorphic sole exhumation in context of absolute plate motions. *Geochemistry, Geophysics, Geosystems*, **16**, 1771–1785, https://doi.org/10.1002/2015GC005745.

van Hinsbergen, D.J.J., Torsvik, T.H., et al. 2020. Orogenic architecture of the Mediterranean region and kinematic reconstruction of its tectonic evolution since the Triassic. *Gondwana Research*, **81**, 79–229, https://doi.org/10.1016/j.gr.2019.07.009.

van Hinsbergen, D.J.J., Lamont, T.N. and Guilmette, C. 2024. Lithospheric unzipping explaining hot orogenesis during continental subduction. *EarthArxiv*, https://doi.org/https://doi.org/10.31223/X59129.

van Staal, C.R. and Barr, S.M. 2012. Lithospheric architecture and tectonic evolution of the Canadian Appalachians and associated Atlantic margin. *In*: Percival, J. A. (ed.) *Tectonic Styles in Canada: The LITHOPROBE Perspective*. 41–95.

van Staal, C.R. and Dewey, J.F. 2023. A review and tectonic interpretation of the Taconian– Grampian tract between Newfoundland and Scotland: diachronous accretion of an extensive forearc–arc–backarc system to a hyperextended Laurentian margin and subsequent subduction polarity reversal. *Geological Society Special Publication*, **531**, 11–46, https://doi.org/10.1144/SP531-2022-152.

van Staal, C.R. and Zagorevski, A. 2020. Accretion, soft and hard collision: Similarities, differences and an application from the Newfoundland Appalachian orogen. *Geoscience Canada*, **47**, 103–118, https://doi.org/10.12789/geocanj.2020.47.161.

van Staal, C.R. and Zagorevski, A. 2023. Paleozoic tectonic evolution of the rifted margins of Laurentia. *In*: *Turning Points in the Evolution of a Continent: Geological Society of America Memoir*. 487–503., https://doi.org/10.1130/2022.1220(24).

van Staal, C.R., Sullivan, R.W. and Whalen, J.B. 1996. Provenance and tectonic history of the Gander Zone in the Caledonian/Appalachian orogen: Implications for the origin and assembly of Avalon. *Geological Society of America Special Paper*.

van Staal, C.R., Dewey, J.F., Mac Niocaill, C. and McKerrow, W.S. 1998. The Cambrian-Silurian tectonic evolution of the northern Appalachians and British Caledonides: history of a complex, west and southwest Pacific-type segment of Iapetus. *In*: Blundell, D. J. and Scott, A. C. (eds) *Lyell: The Past Is the Key to the Present*. 199–242.

van Staal, C.R., Whalen, J.B., et al. 2007. The Notre Dame Arc and the Taconic orogeny in Newfoundland. *Memoir of the Geological Society of America*, **200**, 511–552, https://doi.org/10.1130/2007.1200(26).

van Staal, C.R., Currie, K.L., Rowbotham, G., Goodfellow, W. and Rogers, N. 2008. Pressure-temperature paths and exhumation of Late Ordovician-Early Silurian blueschists and associated metamorphic nappes of the Salinic Brunswick subduction complex, northern Appalachians. *Bulletin of the Geological Society of America*, **120**, 1455–1477, https://doi.org/10.1130/B26324.1.

van Staal, C.R., Whalen, J.B., Valverde-Vaquero, P., Zagorevski, A. and Rogers, N. 2009. Pre-Carboniferous, episodic accretion-related, orogenesis along the Laurentian margin of the northern Appalachians. *Geological Society Special Publication*, **327**, 271–316, https://doi.org/10.1144/SP327.13.

van Staal, C.R., Chew, D.M., et al. 2013. Evidence of Late Ediacaran hyperextension of the Laurentian Iapetan margin in the Birchy Complex, Baie Verte Peninsula, northwest Newfoundland: Implications for the opening of Iapetus, formation of peri-Laurentian microcontinents and Taconic - Grampian orogenesis. *Geoscience Canada*, **40**, 94–117, https://doi.org/10.12789/geocanj.2013.40.006.

van Staal, C.R., Zagorevski, A., McNicoll, V.J. and Rogers, N. 2014. Time-transgressive Salinic and Acadian orogenesis, magmatism and old red sandstone sedimentation in Newfoundland. *Geoscience Canada*, **41**, 138–164, https://doi.org/10.12789/geocanj.2014.41.031.

van Staal, C.R., Wilson, R.A., Kamo, K.L., McClelland, W.C. and McNicoll, V.J. 2016. Evolution of the early to middle Ordovician Popelogan arc in New Brunswick, Canada, and adjacent Maine, USA : Record of arc-trench migration and multiple phases of rifting. *Bulletin of the Geological Society of America*, **128**, 122–146, https://doi.org/10.1130/B31253.1.

van Staal, C.R., Barr, S.M., Waldron, J.W.F., Schofield, D.I., Zagorevski, A. and White, C.E. 2021a. Provenance and Paleozoic tectonic evolution of Ganderia and its relationships with Avalonia and Megumia in the Appalachian-Caledonide orogen. *Gondwana Research*, **98**, 212–243, https://doi.org/10.1016/j.gr.2021.05.025.

van Staal, C.R., Barr, S.M., McCausland, P.J.A., Thompson, M.D. and White, C.E. 2021b. Tonian–Ediacaran tectonomagmatic evolution of West Avalonia and its Ediacaran–Early Cambrian interactions with Ganderia: An example of complex terrane transfer due to arc–arc collision? *In*: *Geological Society Special Publication*. 143–167., https://doi.org/10.1144/SP503-2020-23.

van Staal, C.R., Lin, S., Valverde-Vaquero, P., Dunning, G., Burgess, J., Schofield, D. and Joyce, N. 2024. Tectonic evolution of high-grade metamorphic tectonites of the Meelpaeg structure near Port aux Basques, southwestern Newfoundland during the Silurian Salinic and Early-to-Middle Devonian Acadian orogenies. *Canadian Journal of Earth Sciences*, https://doi.org/10.1139/cjes-2023-0141.

Wakabayashi, J. 2021. Field and petrographic reconnaissance of Franciscan complex rocks of Mount Diablo, California: Imbricated ocean floor stratigraphy with a roof exhumation fault system. *In*: *Regional Geology of Mount Diablo, California: Its Tectonic Evolution on the North America Plate Boundary. Geological Society of America Memoirs*.

Wakabayashi, J. and Dilek, Y. 2000. Spatial and temporal relationships between ophiolites and their metamorphic soles: A test of models of forearc ophiolite genesis. *Geological Society of America Special Papers*, **349**, 53–64.

Wakita, K. 2015. OPS mélange: A new term for mélanges of convergent margins of the world. *International Geology Review*, **57**, 529–539, https://doi.org/10.1080/00206814.2014.949312.

Waldron, J.W.F. 2019. *Tectonics of the West Newfoundland Appalachians: A Field Guide*.

Waldron, J.W.F. and Palmer, S.E. 2000. Lithostratigraphy and structure of the Humber Arm Allochthon in the type area, Bay of Islands, Newfoundland. *Current Research*, 279–290.

Waldron, J.W.F. and Stockmal, G.S. 1994. Structural and tectonic evolution of the Humber Zone, western Newfoundland 2. A regional model for Acadian thrust tectonics. *Tectonics*, **13**, 1498–1513, https://doi.org/10.1029/94TC01505.

Waldron, J.W.F. and van Staal, C.R. 2001. Taconian orogeny and the accretion of the Dashwoods block: A peri-Laurentian microcontinent in the Iapetus Ocean. *Geology*, **29**, 811–814.

Waldron, J.W.F., McNicoll, V.J. and van Staal, C.R. 2012. Laurentia-derived detritus in the Badger Group of central Newfoundland: Deposition during closing of the Iapetus Ocean. *Canadian Journal of Earth Sciences*, **49**, 207–221, https://doi.org/10.1139/E11-030.

Waldron, J.W.F., Barr, S.M., Park, A.F., White, C.E. and Hibbard, J.P. 2015. Late Paleozoic strike-slip faults in Maritime Canada and their role in the reconfiguration of the northern Appalachian orogen. *Tectonics*, **34**, 1661–1684, https://doi.org/10.1002/2015TC003882.

Waldron, J.W.F., Schofield, D.I. and Murphy, J.B. 2018. Diachronous Paleozoic accretion of peri-Gondwanan terranes at the Laurentian margin. *In*: *Fifty Years of the Wilson Cycle Concept in Plate Tectonics*. 289–310., https://doi.org/10.6084/m9.figshare.c.4044332.

Waldron, J.W.F., McCausland, P.J.A., Barr, S.M., Schofield, D.I., Reusch, D. and Wu, L. 2022. Terrane history of the Iapetus Ocean as preserved in the northern Appalachians and western Caledonides. *Earth-Science Reviews*, **233**, https://doi.org/10.1016/j.earscirev.2022.104163.

Wang, C., Wang, T., van Staal, C.R., Hou, Z. and Lin, S. 2024. Evolution of Silurian to Devonian magmatism associated with the Acadian orogenic cycle in eastern and southern Newfoundland Appalachians: Evidence for a three-stage evolution characterized by episodic hinterland- and foreland-directed migration of granitoid magmatism. *Bulletin of the Geological Society of America*, **136**, 4648–4670, https://doi.org/10.1130/B37336.1.

Wasowski, J.J. and Jacobi, R.D. 1985. Geochemistry and tectonic significance of the mafic volcanic blocks in the Dunnage melange, north central Newfoundland. *Canadian Journal of Earth Sciences*, **22**, 1248–1256.

Westhues, A. and Hamilton, M.A. 2018. Geology, lithogeochemistry and U-Pb geochronology of the Baie d’Espoir Group and intrusive rocks, St. Alban’s map area, Newfoundland. *Current Research*, 207–232.

Whalen, J.B., Currie, K.L. and Van Breemen, O. 1987. Episodic Ordovician-Silurian plutonism in the Topsails igneous terrane, western Newfoundland. *Transactions of the Royal Society of Edinburgh: Earth Sciences*, **78**, 17–28.

Whalen, J.B., Jenner, G.A., Longstaffe, F.J., Robert, F. and Gariepy, C. 1996. Geochemical and Isotopic (O, Nd, Pb and Sr) Constraints on A-type Granite Petrogenesis Based on the Topsails Igneous Suite, Newfoundland Appalachians. *Journal of Petrology*, **37**, 1463–1489.

Whalen, J.B., Van Staal, C.R., Longstaffe, F.J., Gariépy, C. and Jenner, G.A. 1997. Insights into tectonostratigraphic zone identification in southwestern Newfoundland based on isotopic (Nd, O, Pb) and geochemical data. *Atlantic Geology*, **33**, 231–241.

Whalen, J.B., McNicoll, V.J., van Staal, C.R., Lissenberg, C.J., Longstaffe, F.J., Jenner, G.A. and van Breeman, O. 2006. Spatial, temporal and geochemical characteristics of Silurian collision-zone magmatism, Newfoundland Appalachians: An example of a rapidly evolving magmatic system related to slab break-off. *Lithos*, **89**, 377–404, https://doi.org/10.1016/j.lithos.2005.12.011.

Whalen, J.B., Zagorevski, A., McNicoll, V.J. and Rogers, N. 2013. Geochemistry, U-Pb geochronology, and genesis of granitoid clasts in transported volcanogenic massive sulfide ore deposits, Buchans, Newfoundland. *Canadian Journal of Earth Sciences*, **50**, 1116–1133, https://doi.org/10.1139/cjes-2013-0040.

White, S.E. and Waldron, J.W.F. 2019. Inversion of Taconian extensional structures during Paleozoic orogenesis in western Newfoundland. *Geological Society Special Publication*, **470**, 311–336, https://doi.org/10.1144/SP470.17.

White, S.E. and Waldron, J.W.F. 2022. Along-strike variations in the deformed Laurentian margin in the Northern Appalachians: Role of inherited margin geometry and colliding arcs. *Earth-Science Reviews*, **226**, https://doi.org/10.1016/j.earscirev.2022.103931.

Williams, H. 1964. The Appalachians in northeastern Newfoundland; a two-sided symmetrical system. *American Journal of Science*, **262**, 1137–1158, https://doi.org/10.2475/ajs.262.10.1137.

Williams, H. 1977. The Coney Head Complex: another Taconic allochthon in west Newfoundland. *American Journal of science*, **277**, 1279–1295.

Williams, H. 1979. Appalachian Orogen in Canada. *Canadian Journal of Earth Sciences*, **16**, 792–807.

Williams, H. 1995. *Geology of the Appalachian-Caledonian Orogen in Canada and Greenland*.

Williams, H. and Cawood, P.A. 1989. Geology, Humber Arm Allochthon, Newfoundland. *Geological Survery of Canada, map 1678A, scale 1:250000*.

Williams, H. and Hiscott, R.N. 1987. Definition of the Iapetus rift-drift transition in western Newfoundland. *Geology*, **15**, 1044–1047.

Williams, H. and Piasecki, M.A.J. 1990. The Cold Spring Mélange and a possible model for Dunnage-Gander zone interaction in central Newfoundland. *Canadian Journal of Earth Sciences*, **27**, 1126–1134.

Williams, H., St-Julien, P. and Béland, J. 1982. The Baie Verte-Brompton line: early Paleozoic continent-ocean interface in the Canadian Appalachians. *In*: *Major Structural Zones and Faults of the Northern Appalachians*. 177–207.

Williams, H., Colman-Sadd, S.P. and Swinden, H.S. 1988. Tectonic-stratigraphic subdivisions of central Newfoundland. *Current Research*, **88-1B**, 91–98.

Williams, H., Currie, K.L. and Piasecki, M.A.J. 1993. The Dog Bay Line: a major Silurian tectonic boundary in northeast Newfoundland. *Canadian Journal of Earth Sciences*, **30**, 2481–2494.

Williams, S.H. 1991. Stratigraphy and graptolites of the Upper Ordovician Point Leamington Formation, central Newfoundland. *Canadian Journal of Earth Sciences*, **28**, 581–600, https://doi.org/10.1139/e91-051.

Williams, S.H. 1992. Lower Ordovician (Arenig-Llanvirn) graptolites from the Notre Dame Subzone, central Newfoundland. *Canadian Journal of Earth Sciences*, **29**, 1717–1733, https://doi.org/10.1139/e92-135.

Willner, A.P., Gerdes, A., Massonne, H.J., van Staal, C.R. and Zagorevski, A. 2014. Crustal evolution of the Northeast Laurentian margin and the peri-Gondwanan microcontinent Ganderia prior to and during closure of the Iapetus Ocean: Detrital zircon U–Pb and Hf isotope evidence from Newfoundland. *Geoscience Canada*, **41**, 345–364, https://doi.org/10.12789/geocanj.2014.41.046.

Willner, A.P., Glodny, J., Massonne, H.-J., van Staal, C. and Zagorevski, A. 2015. P-T-t evolution of high pressure rocks during an Ordovician arc-continent collision at the margin of Laurentia in western Newfoundland (Canada). *In*: *International Eclogite Conference, Abstract Volume*. 104.

Willner, A.P., van Staal, C.R., Glodny, J., Sudo, M. and Zagorevski, A. 2022. Conditions and timing of metamorphism near the Baie Verte Line (Baie Verte Peninsula, NW Newfoundland, Canada): Multiple reactivations within the suture zone of an arc-continent collision. *In*: *Special Paper of the Geological Society of America*. 209–241., https://doi.org/10.1130/2022.2554(09).

Wilson, J.T. 1966. Did the Atlantic close and then re-open? *Nature*, **211**, 676–681.

Wilson, R.A., van Staal, C.R. and McClelland, W.C. 2015. Synaccretionary sedimentary and volcanic rocks in the ordovician Tetagouche backarc Basin, New Brunswick, Canada: Evidence for a transition from foredeep to forearc basin sedimentation. *American Journal of Science*, **315**, 958–1001, https://doi.org/10.2475/10.2015.03.

Wright, D.T. and Knight, I. 1995. A revised chronostratigraphy for the lower Durness Group. *Scottish Journal of Geology*, **31**, 11–22, https://doi.org/10.1144/sjg31010011.

Yan, W. and Casey, J.F. 2020. A new concordia age for the 'forearc' Bay of Islands Ophiolite Complex, Western Newfoundland utilizing spatially-resolved LA-ICP-MS U-Pb analyses of zircon. *Gondwana Research*, **86**, 1–22, https://doi.org/10.1016/j.gr.2020.05.007.

Yan, W. and Casey, J.F. 2022. New U-Pb zircon ages of plagiogranites from the Coastal Complex ophiolite and Twillingate batholith, Newfoundland: Evidence for the oldest and overlapping silicic magmatism in the nascent Cambrian peri-Laurentia forearc and arc terranes. *Gondwana Research*, **110**, 165–196, https://doi.org/10.1016/j.gr.2022.06.008.

Yan, W. and Casey, J.F. 2023. Synchronous formation of the 'forearc' Bay of Islands ophiolite and its basal high-temperature metamorphic sole constrained by U–Pb zircon ages. *Geoscience Frontiers*, **14**, https://doi.org/10.1016/j.gsf.2023.101649.

Yan, W., Casey, J.F. and Webb, L.E. 2025. Cooling history of the Bay of Islands Complex sub-ophiolitic metamorphic sole constrained by new mica 40Ar/39Ar thermochronology: Tectonic implications and comparison with the Semail sole. *Earth and Planetary Science Letters*, **656**, https://doi.org/10.1016/j.epsl.2025.119269.

Zagorevski, A. and McNicoll, V. 2012. Evidence for seamount accretion to a peri-Laurentian arc during closure of Iapetus. *Canadian Journal of Earth Sciences*, **49**, 147–165, https://doi.org/10.1139/E11-016.

Zagorevski, A. and van Staal, C.R. 2002. Structures associated with the Red Indian Line in southwestern Newfoundland. *Current Research*, 211–218.

Zagorevski, A. and van Staal, C.R. 2011. The record of Ordovician arc-arc and arc-continent collisions in the Canadian Appalachians during the closure of Iapetus. *Frontiers in Earth Sciences*, **4**, 341–371, https://doi.org/10.1007/978-3-540-88558-0_12.

Zagorevski, A., Rogers, N., van Staal, C.R., McNicoll, V.J., Lissenberg, C.J. and Valverde-Vaquero, P. 2006. Lower to Middle Ordovician evolution of peri-Laurentian arc and backarc complexes in Iapetus: Constraints from the Annieopsquotch accretionary tract, central Newfoundland. *Bulletin of the Geological Society of America*, **118**, 324–342, https://doi.org/10.1130/B25775.1.

Zagorevski, A., van Staal, C.R. and McNicoll, V.J. 2007. Distinct Taconic, Salinic, and Acadian deformation along the Iapetus suture zone, Newfoundland Appalachians. *Canadian Journal of Earth Sciences*, **44**, 1567–1585, https://doi.org/10.1139/E07-037.

Zagorevski, A., van Staal, C.R., McNicoll, V.J., Rogers, N. and Valverde-Vaquero, P. 2008. Tectonic architecture of an arc-arc collision zone, Newfoundland Appalachians. *Special Paper of the Geological Society of America*, **436**, 309–333, https://doi.org/10.1130/2008.2436(14).

Zagorevski, A., Van Staal, C.R., Rogers, N., McNicoll, V.J. and Pollock, J. 2010. Middle Cambrian to Ordovician arc-backarc development on the leading edge of Ganderia, Newfoundland Appalachians. *Memoir of the Geological Society of America*, **206**, 367–396, https://doi.org/10.1130/2010.1206(16).

Zagorevski, A., van Staal, C.R., McNicoll, V.J., Hartree, L. and Rogers, N. 2012. Tectonic evolution of the Dunnage Mélange tract and its significance to the closure of Iapetus. *Tectonophysics*, **568–569**, 371–387, https://doi.org/10.1016/j.tecto.2011.12.011.

Zagorevski, A., McNicoll, V., Van Staal, C.R., Kerr, A. and Joyce, N. 2014. From large zones to small terranes to detailed reconstruction of an early to Middle ordovician arc – Backarc system preserved along the Iapetus suture zone: A legacy of Hank Williams. *Geoscience Canada*, **42**, 125–150, https://doi.org/10.12789/geocanj.2014.41.054.

Zagorevski, A., McNicoll, V.J., Rogers, N. and van Hees, G.H. 2016. Middle Ordovician disorganized arc rifting in the peri-Laurentian Newfoundland Appalachians: Implications for evolution of intra-oceanic arc systems. *Journal of the Geological Society*, **173**, 76–93, https://doi.org/10.1144/jgs2015-003.

Zagorevski, A., van Staal, C.R. and Joyce, N.L. 2024. The provenance and tectonic history of Dashwoods and the associated Baie Verte Margin during the Ordovician to Silurian. *Geological Society, London, Special Publications*, **542**, https://doi.org/10.1144/sp542-2023-20.

FIGURE CAPTIONS

Figure 1 – Paleogeographic reconstructions at ca. 500 Ma (a, Domeier 2016; b, Merdith *et al.* 2021; c, van Staal and Zagorevski 2023; modified from Gasser *et al.* 2024) and at ca. 450 Ma (d, van Staal *et al.* 1998; e, Pollock *et al.* 2011; f, Domeier 2016). Projections are taken from the original authors and were not adapted. The reconstructions show different paleogeographic and subduction configurations for the same time step, as the interpretations derive from different datasets. Abbreviations for the microcontinents: ARM=Armorica; AV=Avalonia; CA=Carolina; DW=Dashwoods; EA=East Avalonia; GA=Ganderia; WA=West Avalonia.

Figure 2 - Example of the elements making up an orogenic architecture diagram, and of the type-tectonic units with paleogeographic significance which can be found in an orogenic belt. The 'Map colours' at the top of each column refer to the colours each fault-bounded unit is assigned in a map of the region of interest. The colours and patterns presented in this infographic only serve as an example of lithological classification and interpretation, and can be adjusted.

Figure 3 – A) Simplified geological map of Newfoundland, adapted from Colman-Sadd *et al.* (2000). Trace of the major NE-SW structural features is from Waldron *et al.* (2015); Willner *et al.* (2022). The two northwest-southeast lines represent the trace of the orogenic architecture diagrams of Fig. 4a, 4b. Note that each colour and pattern (see legend in B) represents one of the tectonic units described in the text, and is represented by a column in Fig. 4. Abbreviations: BDE=Baie d'Espoir Group, BDN=Bay du Nord Group, BOIC=Bay of Islands Complex, BVO=Baie Verte Ophiolite, BWG=Botwood Group, CBLB=Corner Brook Lake Block, CC=Coastal Complex, CHC=Coney Head Complex, CP=Coy Pond ophiolite, DVG=Davidsville Group, EXP=Exploits Group, FDL=Fleur de Lys Supergroup, GG=Gander Group, GRC=Gander River Complex, HBG=Hare Bay Gneiss, HSG=Hamilton Sound Group, IAG=Indian Islands Group, LB=Lush's Bight ophiolite, LRC=Long Range mafic-ultramafic Complex, MCT=Mount Cormack Terrane, MPN=Meelpaeg Nappe, NDA=Notre Dame Arc, PAB=Port-aux-Basques Complex, PFF=Pine Falls Formation, PP=Pipestone Pond ophiolite, RAB=Robert's Arm belt, RCG=Red Cross Group, SA=St. Anthony ophiolite, SFG=Summerford Group, SPG=Springdale Group, VLS=Victoria Lake Supergroup, WBG=Wild Bight Group, WPG=Windsor Point Group.

Figure 4 – Orogenic architecture diagrams of A) northern Newfoundland and B) central-southern Newfoundland; the legend in (B) refers to both diagrams. Geologic timescale from Gradstein and Ogg (2020). The trace of the transects can be found in Fig. 3. The 'Map colours' at the bottom of each column are the colours with which each unit is depicted in the map in Fig. 3; in the case of units overlying one another, the colour boxes are in the same stratigraphic order and have the same width as the unit they represent. Abbreviations of the geochemical signatures: BON=boninite; CA=calc-alkaline; E-MORB=enriched mid-ocean ridge basalt; IAT=island-arc tholeiite; (N-)MORB=(normal) mid-ocean ridge basalt; OIB=ocean island basalt; PC= post-collisional; SSZ=suprasubduction zone; TIAT=transitional island-arc tholeiite; VAG=volcanic-arc granite; WPG=within-plate granite. Abbreviations of the lithological units (italics): BDE=Baie d'Espoir Group, BDN=Bay du Nord Group, BG=Badger Group, BWG=Botwood Group, CBCL=Corner Brook Lake Block,

DVG=Davidsville Group, FDL=Fleur de Lys Supergroup, IAG=Indian Islands Group, PA=Penobscot Arc, RCG=Red Cross Group, SBG=Sandy Brook Group, SPG=Springfield Group, VA=Victoria Arc.

Figure 5 - Schematic cross-sections (NW-SE) of the evolution of the Newfoundland Appalachians during the orogeny, from the Neoproterozoic (a) to the Devonian (h). Cross-sections (a) to (c) refer to the Laurentian side of the Iapetus Ocean only, and are subdivided in North and South following the two orogenic architecture diagrams in Fig. 4. Cross-section (d) refers to the Gondwanan side of the Iapetus Ocean only, is coeval with cross-sections (a)-(c) and is based on the orogenic architecture diagram of Fig. 4b. Cross-sections (e) to (h) refer to both sides of the Iapetus Ocean and are based on the orogenic architecture diagram of Fig. 4b. Dashed lines indicate features that are inferred and for which evidence is not conclusive. Abbreviations: BOIC=Bay of Islands Complex, BVO=Baie Verte Ophiolites, CC=Coastal Complex, LB=Lush's Bight, NDA=Notre Dame Arc.

Figure 6 - Flow chart showing where the orogenic architecture diagrams are positioned in the logic sequence from geological data to large scale reconstructions.