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# A COMPARATIVE ANALYSIS OF PRE-SILURIAN CRUSTAL BUILDING BLOCKS OF THE NORTHERN AND THE SOUTHERN APPALACHIAN OROGEN

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**ABSTRACT. The New York promontory serves as the divide between the northern and southern segments of the Appalachian orogen. Antiquated subdivisions, distinct for each segment, implied that they had lithotectonic histories that were independent of each other. Using new lithotectonic subdivisions we compare first order features of the pre-Silurian orogenic 'building blocks' in order to test the validity of the implication of independent lithotectonic histories for the two segments.**

**Three lithotectonic divisions, termed here the Laurentian, Iapetan, and the peri-Gondwanan realms, characterize the entire orogen. The Laurentian realm, composed of native North American rocks, is remarkably uniform for the length of the orogen. It records the multistage Neoproterozoic-early Paleozoic rift-drift history of the Appalachian passive margin, formation of a Taconic Seaway, and the ultimate demise of both in the Middle Ordovician. The Iapetan realm encompasses mainly oceanic and magmatic arc tracts that once lay within the Iapetus Ocean, between Laurentia and Gondwana. In the northern segment, the realm is divisible on the basis of stratigraphy and faunal provinciality into peri-Laurentian and peri-Gondwanan tracts that were amalgamated in the Late Ordovician. South of New York, stratigraphic and faunal controls decrease markedly; rock associations are not inconsistent with those of the northern Appalachians, although second-order differences exist. Exposed exotic crustal blocks of the peri-Gondwanan realm include Ganderia, Avalonia, and Meguma in the north, and Carolinia in the south. Carolinia most closely resembles Ganderia, both in early evolution and Late Ordovician-Silurian docking to Laurentia.**

**Our comparison indicates that, to a first order, the pre-Silurian Appalachian orogen developed uniformly, starting with complex rifting and a subsequent drift phase to form the Appalachian margin, followed by the consolidation of Iapetan components and ending with accretion of the peri-Gonwanan Ganderia and Carolinia. This deduction implies that any first-order differences between northern and southern segments post-date Late Ordovician consolidation of a large portion of the orogen.**

## INTRODUCTION

The Appalachian orogen (fig. 1) is the northeast-trending belt of Mesoproterozoic to Paleozoic rocks in eastern North America that was deformed during the Paleozoic (Rodgers, 1970). The structural grain of the orogen is remarkably consistent, defining a series of broad, harmonically curved promontories and embayments (fig. 1). These structural bends have been used to delineate segments of the orogen termed the southern (Alabama promontory-Virginia promontory), central (or middle, Virginia promontory-New York promontory), northern (New York promontory-St. Lawrence promontory), and Newfoundland Appalachians (north of St. Lawrence promontory) (Rodgers, 1949, 1970) (fig. 1); however, commonly in modern parlance, the New York promontory, located near the center and at the narrowest part of the orogen, serves as the divide between two segments referred to herein as the northern and southern Appalachians.

Originally, a contrast developed in the manner of subdivision of these two segments of the orogen. The traditional geological belts of the southern Appalachians were based on a commonality of rocks and structures, and generally corresponded to

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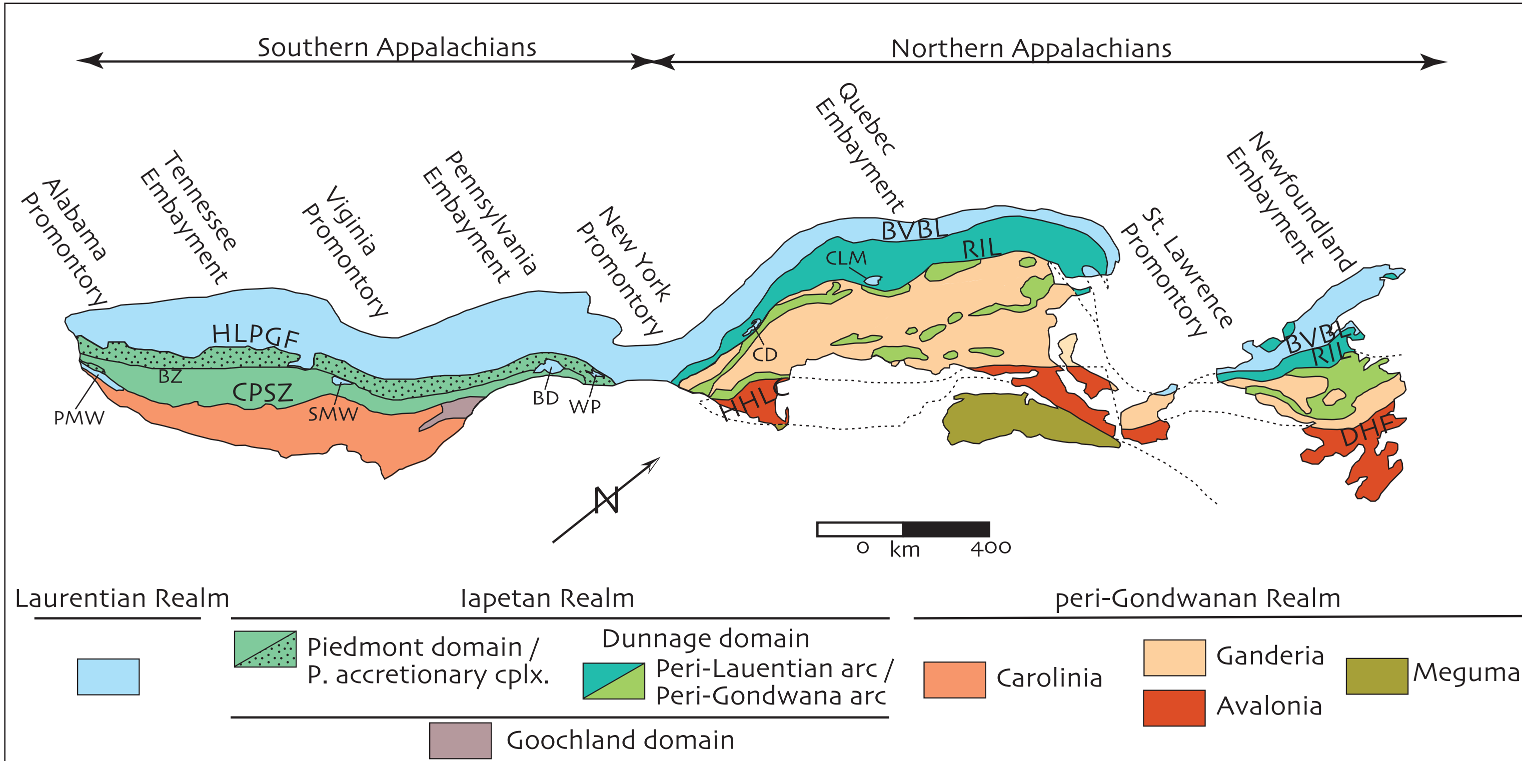


Fig. 1. Major pre-Silurian lithotectonic divisions of the Appalachian orogen. BVBL=Baie Verte - Brompton Line; BD=Baltimore domes; BZ=Brevard zone; CD=Chester dome; CLM=Chain Lakes massif; CPSZ=central Piedmont shear zone; DHF=Dover-Hermitage Bay faults; HHLC=Honey Hill - Lake Char fault system; HLPGF=Hollins Line - Pleasant Grove fault system; PMW=Pine Mountain window; RIL=Red Indian Line; SMW=Sauratown Mountains window; WP=Westchester prong.

physiographic divisions, such as the Plateau, Valley and Ridge, Blue Ridge, and Piedmont provinces (King, 1955). In contrast, subdivision of the northern Appalachians was based on large-scale structures of geanticlines and geosynclines (for example, Schuchert and Dunbar, 1934) that evolved into anticlinoria and synclinoria (for example, Rodgers, 1970). All of these systems were replaced first by zonal subdivisions (Williams, 1978) and later by terrane subdivisions, both of which were applicable to the entire orogen (Williams and Hatcher, 1983). The contrast in the older subdivisional systems has subliminally lingered, instilling in many workers the perception that the two segments of the orogen have distinct lithotectonic histories. Such a difference is valid, in part, for the mid to late Paleozoic history of the orogen. However, during recent compilation of the new lithotectonic map of the Appalachian orogen (Hibbard and others, 2006) we became impressed by the commonality of many pre-Silurian lithotectonic elements in the orogen. This realization prompted the authors to explore the potential correlation of first-order pre-Silurian rock assemblages and geologic events between the southern and northern Appalachians; that is, can we bring geology from one segment of the Appalachians to the other? It is also timely, now, to undertake this analysis, for in compiling the new lithotectonic map we realized that new concepts developed in each segment have bearing on the interpretation of the entire orogen.

This contribution is based on, and evolved with, the new lithotectonic map of the Appalachian orogen (Hibbard and others, 2006). In both we use lithotectonic divisions to distinguish rock affiliations that were either formed or deposited in a common tectonic setting during a finite time span (Hibbard, 2004). They are scale dependent, contingent on the scale of the tectonic process considered. The hierarchy of lithotectonic divisions we use consists of the *realm* at orogen scale and the *domain* at the scale of two or less embayments. These subdivisions refine the zone system (Williams, 1978) in which some zones were of orogen scale, whereas others were more limited in extent. At yet smaller scale, *terranes* are here recognized as regional subdivisions of a domain and used in the sense of Coney and others (1980). Considering the overview nature of this essay, we will be concerned with realms and domains. We will show that many pre-Silurian lithotectonic units are similar for most of the length of eastern North America and that these units form the fundamental building blocks of the Appalachian orogen. Younger lithotectonic units and subsequent tectonic events are superposed on this framework.

## Lithotectonic Components of the Orogen

The Appalachian orogen is composed of three realms, Laurentian, Iapetan, and peri-Gondwanan (fig. 1), all of which acquired their defining geologic character before the Late Ordovician. The Laurentian realm (Laurentian Appalachians of Rankin, 1994) encompasses essentially all of the rocks deposited either on or immediately adjacent to ancient North America and forms the western flank of the entire orogen; however structural windows of Laurentian rocks occur locally among the more easterly accreted terranes (fig. 1). In contrast, components of the peri-Gondwanan realm along the southeastern flank of the orogen formed proximal to Gondwana and thus they are exotic with respect to Laurentian elements. The Iapetan realm is a collection of domains and terranes of oceanic and volcanic arc affinity that have been caught between the Laurentian and peri-Gondwanan realms during Appalachian orogenesis. One Appalachian crustal element, the Goochland domain, defies realm assignment (fig. 1). It is a continental crustal block containing c. 1 Ga orthogneiss and anorthosite enveloped in high-grade paragneiss (Farrar, 1984; Owens and Tucker 2003); this oddity is of ambiguous provenance, be it a structural window of the Laurentian realm or an exotic accreted block (see Horton and others, 1989; Owens and Tucker, 2003), and insufficient data about its lithotectonic history preclude its further discussion in this manuscript.

At the narrowest part of the orogen on the New York promontory, the Atlantic coastal plain cover cuts across the orogen as far west as the Laurentian realm, effectively forming a divide between northern and southern segments of the Iapetan and peri-Gondwanan realms. This lack of contiguity between the two segments of these realms exacerbates the problem of comparing their first-order components.

### *Laurentian Realm*

The template for Appalachian accretionary events, the eastern Laurentian continental margin, or Laurentian realm, was initiated by Neoproterozoic-earliest Paleozoic rifting along the axis of the Mesoproterozoic Grenville orogen within Rodinia; thus Grenville rocks formed basement to the continental margin. The west flank of the Amazonian craton has been commonly cited as forming the conjugate margin to eastern Laurentia during this extensional event (for example, Dalziel, 1992; Sadowski and Bettencourt, 1996; Cawood and Pisarevsky, 2006). In light of limited extant data sets that bear on this problem, Amazonia is a permissible, but not necessarily a unique, solution.

In addition to Grenvillian basement, major defining lithotectonic components of the Laurentian realm include a Neoproterozoic rift sequence resulting from the breakup of this basement, an overlying Early Cambrian to Middle Ordovician drift sequence related to thermal subsidence of the rifted margin during the growth of the Iapetus Ocean, and a Middle to Late Ordovician series of easterly-derived clastic wedges that record subduction, and hence demise, of the Laurentian passive margin.

The modern sinuous structural trend of orogenic promontories and embayments was inherited from the original pattern of the eastern, rifted Laurentian margin (Rodgers, 1975; Rankin, 1975, 1976; Thomas, 1977); specifically, the geometry of the continental margin was controlled by the orthogonal zig-zag pattern formed by spreading and transform segments of the rift system (Rodgers, 1975; Thomas, 1977, 1991). This shape influenced the distribution of ensuing rift and drift sequences; former ridge-transform junctions along the margin tended to form steep-sided terminations for rift basins, whereas the distribution of the drift sequence facies change from shelf to slope and rise was controlled by the jagged shape of the margin (Rodgers, 1968; Thomas, 1977).

The most noteworthy characteristic of the realm is its remarkable overall uniformity compared to the more variable Iapetan and peri-Gondwana realms. In particular, the rift-drift transition and the ensuing early Paleozoic drift sequence show very little first-order variation from Alabama to Newfoundland (for example, Rodgers, 1968; Thomas, 1977; James and others, 1989; Rankin, 1994; Lavoie and others, 2003). Stratigraphic evidence along the length of the realm indicates that rift facies strata terminate close to the Neoproterozoic - Cambrian boundary (c. 542 Ma) and that drift facies strata, here termed the Appalachian margin (after Thomas, 1977), appear in the Early Cambrian (Thomas, 1977)(fig. 2). Where studied in detail in the southern Appalachians, the transition from rift strata to drift strata has been interpreted to take place in the earliest Cambrian (Simpson and Eriksson, 1989). In the northern Appalachians, the timing of the rift-drift transition is not as well constrained. Locally, as in western Newfoundland, an unconformity between rift facies and the ensuing Lower Cambrian drift facies rocks could record a time gap as long as 90 m.y.; however, circumstantial evidence led Cawood and others (2001) to suggest that the drift facies rocks are no older than Early Cambrian. Other workers envisage the rift-drift transition as taking place over a more protracted time period encompassing the Early Cambrian (Lavoie and others, 2003). Regardless, the deposition of extensive, continuous sheets of carbonate characteristic of drift sedimentation appears to have initiated along the

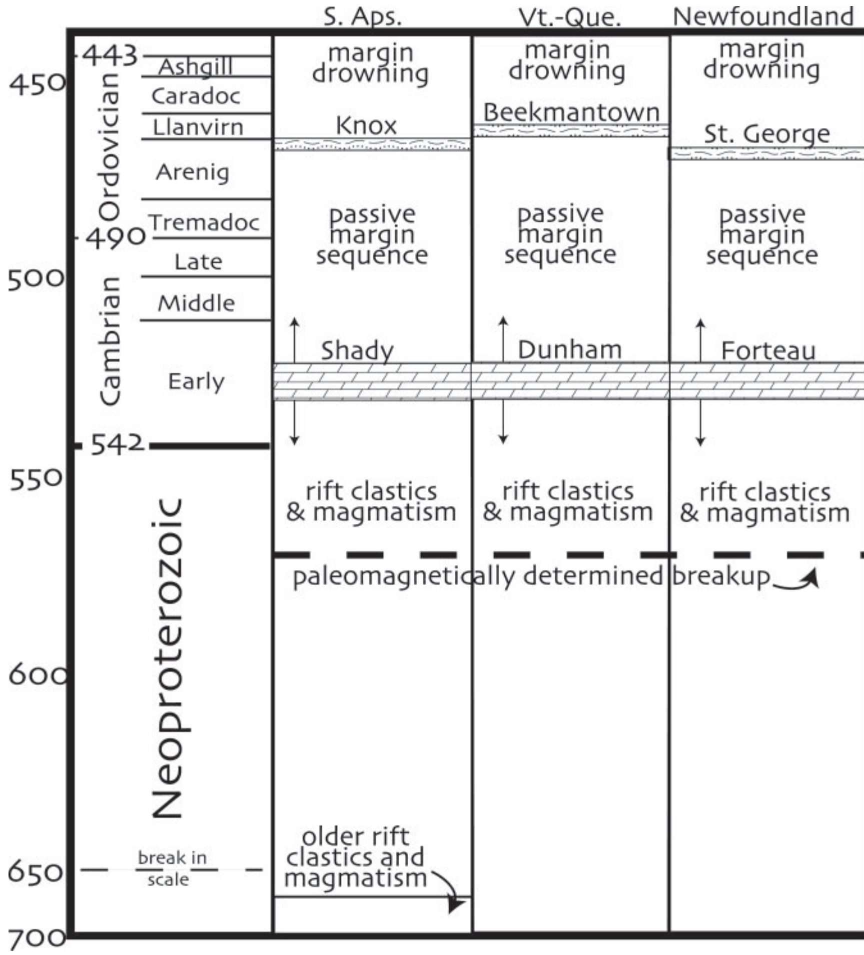


Fig. 2. Neoproterozoic to early Paleozoic features of the Laurentian realm. Parallelogram pattern = first significant carbonate deposition in area; note that limited constraints on age of this carbonate indicate it can range almost anywhere in the Early Cambrian as indicated by arrows. Wavy pattern indicates foreland bulge unconformity related to Taconic loading of the Appalachian margin.

length of the Laurentian realm in the Early Cambrian, implying that the breakup that led to formation of the margin was roughly synchronous throughout the realm (fig. 2). Thus, the stratigraphic record indicates that the Appalachian margin was established in the Early Cambrian and from a first-order perspective, it was notably homogeneous throughout both northern and southern segments of the orogen.

Nonetheless, variations apparent within the realm belie the simplicity of breakup implied by the uniformity of the drift sequence. Specifically, the timing of rift-related magmatism records along-strike variation in the rift history and recent paleomagnetic and stratigraphic studies all strongly suggest multiple episodes of rifting along the margin.

Isotopic ages of rift-related magmatism indicate two broad pulses of rifting, an early pulse (c. 760 – 680 Ma) that is confined to the southern Appalachians (for example, Fetter and Goldberg, 1995; Aleinikoff and others, 1995; Tollo and others, 2004) (fig. 2) and a later, main pulse (c. 620 – 550 Ma) along the length of the orogen (reviewed in Cawood and others, 2001). The early pulse appears to have been coeval with the early breakup of Rodinia along the Pacific margin of Laurentia and it may delineate a failed rift arm related to this event (Cawood and others, 2001), as no known drift deposits are associated with this magmatic pulse. The main pulse of rift magmatism affected the entire length of the Appalachians at c. 620 to 550 Ma (reviewed in Cawood and others, 2001); its late Neoproterozoic termination is consistent with the Early Cambrian rift-drift transition recorded in the stratigraphic record.

Further complexities in the rift history of the Laurentian realm have recently been uncovered in the Newfoundland Appalachians. There it had been difficult to reconcile the timing of the rift to drift transition as constrained by stratigraphic data with available paleomagnetic data that bear on the drift of Laurentia (Cawood and others, 2001). As outlined above, stratigraphic evidence indicates Early Cambrian development of the Appalachian margin. In contrast, paleomagnetic data suggest that Laurentia, while located at a high latitude, rifted from Amazonia at c. 570 Ma and that a substantial tract of the Iapetus Ocean had formed by c. 550 Ma, when Laurentia was at near equatorial latitudes (McCausland and Hodych, 1998). In order to reconcile these seemingly disparate data sets, Cawood and others (2001) proposed that breakup at c. 570 Ma, which led to the drift of Laurentia away from Amazonia and the formation of the Iapetus Ocean, was followed in the late Neoproterozoic to early Paleozoic by the rifting of a continental block or blocks from Laurentia. Thus, any Neoproterozoic passive margin deposits formed during the opening of Iapetus were later spalled from the Laurentian margin aboard ribbon continent(s) during the Early Cambrian rift to drift transition that produced the Appalachian margin. The magmatic record is consistent with this interpretation of a complex rift history (Cawood and others, 2001). Such a scenario would require either a ridge jump into the Laurentian continent or the development of a new rift system just inboard of the Laurentian margin during the latest Neoproterozoic-earliest Paleozoic.

Some workers question the veracity of some of the paleomagnetic data that supports a c. 570 Ma opening of Iapetus, which is substantially earlier than any preserved rift to drift transition strata (for example, Hodych and others, 2004). However, geological, geochronological, and isotopic data from western Newfoundland support the existence of an outboard microcontinent. This block detached from Laurentia, opening a marginal seaway that led to the establishment of the passive margin sequence, and later re-attached to the margin (Waldron and van Staal, 2001). The existence of this microcontinent requires that there was a rift event that post-dated the opening of Iapetus.

An analogous sequence of events has been proposed for the Ouachita embayment, west of the southern termination of the Appalachian orogen. In the embayment, Early Cambrian rift-related igneous rocks along the Southern Oklahoma fault system are nonconformably overstepped by transgressive Late Cambrian strata, indicating that rift and post-rift sedimentary overstep strata are younger than the initiation of the Appalachian margin in the adjacent southern Appalachians (Thomas, 1991). This difference in the timing of rifting is interpreted to reflect a shift in the location of the spreading center responsible for the development of the Appalachian margin. It also appears to have been responsible for the generation of a microcontinent that now constitutes the Precordillera terrane of western Argentina (Thomas and Astini, 1996).

In overview, the development of the Appalachian margin appears to be punctuated by at least two shifts of an oceanic spreading center into the Laurentian continental margin. The first of these shifts, as documented in Newfoundland, records the Early Cambrian opening of a marginal seaway and formation of the Appalachian margin rather than the opening of the main Iapetan tract; the second shift led to the

Late Cambrian generation of the Precordillera microcontinent, a displaced fragment of the Appalachian margin.

Recognition of the nature of the Early Cambrian rift event in Newfoundland has significant ramifications for the development of the entire Laurentian realm. In light of the apparent uniformity of the Appalachian margin stratigraphy throughout the Laurentian realm, this concept implies that the entire Appalachian margin was involved in the rifting of a microcontinent, or series of microcontinents, from the earlier Iapetan margin in the latest Neoproterozoic to early Paleozoic. That is, the lack of evidence for an older Iapetan, passive margin implies that all of eastern Laurentia was rejuvenated by the rifting of a microcontinental block(s) in the latest Neoproterozoic to early Paleozoic to form the Appalachian margin. Potential candidates for such microcontinental blocks abound along the length of the orogen, including any Laurentian affinity structural inliers that lie outboard of the Laurentian realm such as the Chain Lakes massif in Maine and Quebec, the Chester dome in Vermont, the Manhattan prong in New York, the Westchester prong in Pennsylvania, the Baltimore domes in Maryland, the Goochland domain in Virginia, the Sauratown Mountains window in North Carolina and Virginia and the Pine Mountain window in Georgia and Alabama (fig. 1). Many of these inliers have long been suspected of representing either microcontinental blocks or isolated horsts (Hatcher, 1972; Rankin, 1975; Thomas, 1977), but never envisaged to represent collectively such a wholesale rifting of the entire Laurentian margin.

The demise of the Appalachian margin, like its development, was rather uniform along the orogen to a first-order approximation, involving the attempted subduction of Laurentia beneath an overriding arc(s) during the Taconic orogeny (Stevens, 1970; Stanley and Ratcliffe, 1985; Stewart and others, 1997). The initiation of margin drowning and ensuing orogenesis is generally heralded by Middle Ordovician foreland bulge unconformities within carbonate bank deposits (Jacobi, 1981; Knight and others, 1991), collectively known as the Knox-Beekamantown-St. George unconformity; this stratigraphic break was followed soon by deposition of easterly-derived synorogenic clastic-wedges that mark the flexural subsidence of the Appalachian margin and the onset of subduction of the margin (fig. 2). It has long been recognized that drowning of the margin was not synchronous along the length of the orogen; Rodgers (1953, 1971) noted that the Blount clastic wedge (Thomas, 1977) in the Tennessee embayment clearly represented a precocious phase of the Taconic orogeny. Analysis of the timing of shelf drowning across the margin for the length of the orogen indicates that shelf drowning started earliest, during the late Early Ordovician, in Newfoundland (James and Stevens, 1986), followed by early Middle Ordovician initiation in the southern Appalachians. Drowning commenced last in Quebec (Bradley, 1989). The shelf drowning sequence appears to track the migration of a single foredeep from Alabama to Quebec (Bradley, 1989). The differences in timing of Appalachian margin demise could result from diverse potential geometrical configurations of the margin and overriding plate boundary(ies) (Bradley, 1989).

Thus, in summary, the Appalachian margin, template to which outboard, accreted terranes were added, is remarkably similar, to a first order, throughout the realm. Development of the Appalachian margin started everywhere in the Early Cambrian and terminated with the attempted subduction of Laurentia during the closure of a Taconic Seaway during the Middle Ordovician.

### *Iapetan Realm*

Elements of the Iapetan realm record the evolution of the Iapetus Ocean and its associated volcanic arcs, backarc basins, and accretionary complexes. It is divided into two main components, the northern Dunnage domain and the southern Piedmont domain. A major difference exists in the level of understanding of the realm between the two domains. Abundant stratigraphic, paleontological, geochronological, and isotopic data from the Dunnage domain, especially in Newfoundland, allow for the tight resolution of a complex history of multiple volcanic arcs and back arc basins. In the Piedmont domain, however, relevant data markedly decrease, with little stratigraphic control and no documented pre-Middle Ordovician fossils. This contrast in available data sets renders comparison somewhat tenuous between the Dunnage domain, with a tightly constrained, high-resolution lithotectonic history, and the Piedmont domain, with a much less constrained, more abstractly known history.

*Dunnage domain.*—The Dunnage domain is in tectonic contact with the Laurentian realm along the Baie Verte-Brompton Line (fig. 1), a steep, relatively narrow fault system that has experienced multiple episodes of movement (reviewed in Adams and others, 1995). The domain is most fully exposed in north-central Newfoundland, where its entire width is at low metamorphic grade. There, the domain records the evolution of at least two distinct oceanic tracts that are tectonically juxtaposed along the Red Indian Line (Williams and others, 1988; van Staal and others, 1998) (fig. 1). In particular, the peri-Laurentian tract is characterized by a North American, low latitude, fauna in Middle Ordovician and older rocks, common sub-Silurian unconformities, paleomagnetic data that indicate low paleolatitudes, and relatively non-radiogenic Pb isotopic signatures in massive sulphide deposits. In contrast, much of the peri-Gondwanan tract commonly contains a Celtic, mid- to high-paleolatitude fauna, a distinct Caradocian black shale unit that is stratigraphically continuous with Late Ordovician-Silurian marine clastic sequences, paleomagnetic data indicative of middle to high paleolatitudes, and relatively radiogenic Pb isotopic signatures in massive sulphide deposits (Williams and others, 1988; van Staal and others, 1998).

These elements of the Newfoundland Dunnage domain can be correlated with units in New Brunswick, Quebec, and northern Maine, but most Dunnage domain elements from southern Maine to New York are multiply deformed and have been subjected to high-grade metamorphism, thus obscuring original relationships between units. Consequently, the evolution of the domain is not as well understood in New England as in Canada. However, strong hints suggest that the lithotectonic history of the New England portion is consistent with that of the Canadian Dunnage domain (van Staal and others, 1998; Karabinos and others, 1998; van Staal, 2005).

In north-central Newfoundland and the Miramichi Highlands of New Brunswick, where the record is best constrained, both sides of the Iapetus Ocean record complex histories in relatively short time frames - a scenario consistent with processes active in modern oceanic regimes around the margins of the Pacific. The following brief account of the Dunnage domain in this region is distilled from the work of multiple researchers (mainly Colman-Sadd and others, 1992; Swinden and others, 1997; van Staal, 2005; Valverde-Vaquero and others, 2005; van Staal and others, 2007); full evidence for timing and processes are given therein. It should be kept in mind that 1. the tectonic evolution is very tightly constrained, and 2. the details and timing further south in the domain may not be exactly the same as those of the sketch, due in part to the natural heterogeneities inherent in ephemeral marginal basin systems, but also due to the interaction of the marginal basin systems with the irregular shape of the Appalachian margin. It is 'sobering' to realize that the entire domain was originally thought to represent a single island arc built on a continuous slab of Iapetan crust; one can only conjecture as to the complexities that may still lurk in lesser known portions of the domain.

Subduction in both tracts of the Iapetus Ocean initiated in the Early to Middle Cambrian (c. 510 Ma) (fig. 3), the age of the oldest volcanic sequences, all of which exhibit suprasubduction zone geochemical traits. On the peri-Laurentian side subduction likely started adjacent to the microcontinental block rifted from Laurentia in the

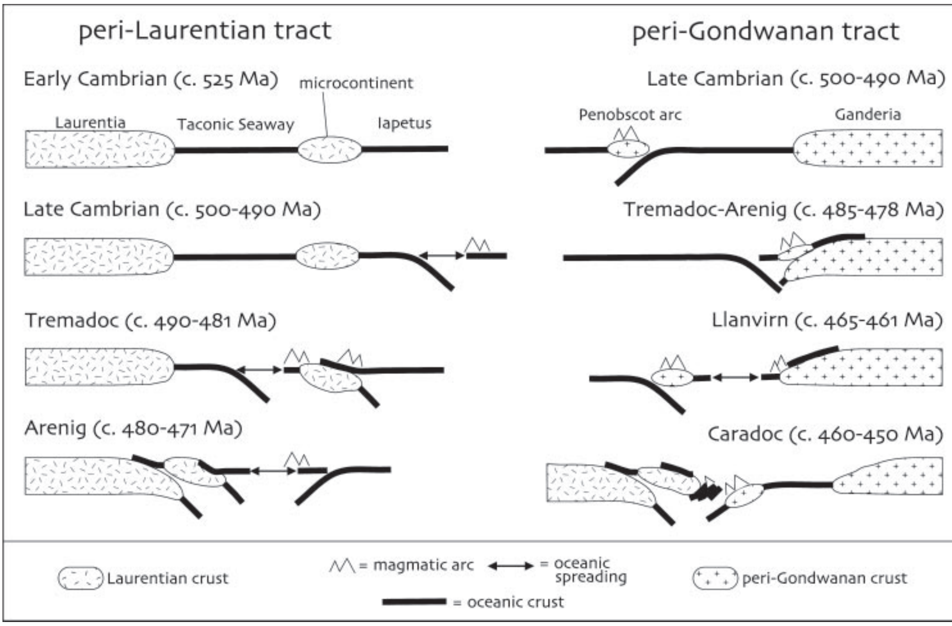


Fig. 3. Stick figure diagram depicting the complex evolution of arc-back arc systems in the Dunnage domain.

late Neoproterozoic-Early Cambrian (see Laurentian realm, above), whereas on the peri-Gondwanan side, at least part of the arc was generated atop of peri-Gondwanan (Ganderian, see below) crust (fig. 3). The peri-Laurentian early arc likely was obducted onto microcontinental crust in the Tremadocian (Swinden and others, 1997), leading to the stepping back of subduction into the Taconic Seaway, where a Tremadocian-Arenigian magmatic arc and associated forearc ophiolitic crust were subsequently generated (van Staal and others, 1998, 2007) (fig. 3). Subduction closed the Taconic Seaway in the Arenigian (Waldron and van Staal, 2001), leading to 1. collisional return of the microcontinent to the Appalachian margin, 2. obduction of Taconic Seaway oceanic crust onto the Laurentian margin, and 3. development of west-dipping subduction beneath the accreted system (van Staal and others, 1998, 2007) (fig. 3). This configuration appears to have persisted through the Caradocian collision of the peri-Laurentian system with the peri-Gondwanan arc system (see below) and it was terminated by Silurian collision with the peri-Gondwanan realm crust of Ganderia (for example, van Staal and others, 2007).

During the same time frame, a complex oceanic tract was developing in the eastern portion of the domain. Following the formation of an early, Penobscot, arc in the peri-Gondwanan tract, westward subduction beneath the arc led to its Arenig obduction onto the Ganderian peri-Gondwanan margin (Colman-Sadd and others, 1992) and initiation of east-dipping subduction polarity (fig. 3). As a consequence of slab roll-back in this new configuration, a back arc basin, the Tetagouche-Exploits basin, opened along the Ganderian margin during the Arenigian and Middle Ordovician (van Staal, 1994; Valverde-Vaquero and others, 2005). The outboard arc associated with this system was accreted to the peri-Laurentian oceanic system described above in the Caradocian (c. 450 – 454 Ma), while the Tetagouche-Exploits basin persisted as the last vestige of Iapetus until the Late Silurian (Williams and others, 1993; van Staal and others, 1998).

*The Piedmont domain.*—The southern Appalachian Piedmont domain is tectonically severed from Laurentian rocks to the west along a series of faults here termed the Hollins Line-Pleasant Grove fault system for the faults anchoring either end of the system (fig. 1); most faults in the system have multiple movement histories and emplace the Piedmont domain over the Laurentian domain (for example, Adams and others, 1995). In terms of lithotectonic evolution, it is one of the least understood of the Appalachian domains. This paucity of knowledge results from the following three main factors:

1. Much of the domain has been subjected to intense mid to lower crustal orogenesis involving polyphase deformation and medium- to high-grade metamorphism (for example, Rodgers, 1970). These conditions destroyed almost all fossil control that may have existed and obliterated primary structures rendering the establishment of stratigraphy in many areas difficult.
2. High-resolution geochronological and geochemical data are sparse compared to the vast, modern data sets of the Dunnage domain.
3. The Piedmont domain has been affected by substantial Alleghanian (Carboniferous) shortening (for example, Hatcher and others, 1989), which is virtually absent in the Dunnage domain. Thus it is difficult to assess whether critical units in the Piedmont domain have been buried beneath thrust sheets (for example, Thomas and others, 2001).

The Piedmont domain is characterized by the presence of rock assemblages that had oceanic crustal and magmatic arc protoliths, although they are not the only components of the domain. It is divided into two major components by the Brevard zone, a polygenetic shear zone, and other faults northward along strike of the Brevard zone (for example, Hatcher, 2002) (fig. 1). The western portion is dominated by metamorphosed clastic rocks and associated block-in-matrix units, with subordinate magmatic arc and oceanic rocks, and local Grenvillian orthogneiss, all of which are disposed in imbricate thrust stacks. On the basis of either the time of metamorphism or the age of intrusive bodies, the age of the metaclastic rocks is generally constrained to Middle Ordovician and older (for example, Aleinikoff and others, 2002; Moecher and others, 2005). Oceanic and magmatic arc rocks in this portion of the domain generally are preserved as tectonic scraps and remnants at different scales within a ubiquitous sea of monotonous metaclastic rocks (for example, Drake and Morgan, 1981; Abbott and Raymond, 1984; Settles, ms, 2002). Available age data indicate a Late Cambrian to Late Ordovician age range for oceanic-arc components of the western Piedmont domain (for example, Drummond and others, 1994; Thomas and others, 2001; Wilson, ms, 2001; Meschter-McDowell and others, 2002; Aleinikoff and others, 2002). Assembly of the thrust stacks has been documented as Ordovician in places (see discussion of Drake, 1987 in Aleinikoff and others, 2002; Stewart and others, 1997), although younger, late Paleozoic thrust stacking has also been documented (summarized in Stewart and others, 1997). Locally, in southwest Virginia and adjacent North Carolina, U-Pb monazite ages suggest that an Early Cambrian (c. 530 Ma) thermal event affected some of the metaclastic rocks (Hibbard and others, 2003a; Moecher and others, 2005). At the western edge of the domain in North Carolina, metaclastic rocks contain map-scale pods of eclogite (Willard and Adams, 1994; Adams and others, 1995) that record Middle to Late Ordovician (c. 460 Ma) peak metamorphism (Miller and others, 2000).

The sum of attributes of the western Piedmont domain listed above has led most workers to conclude that it represents an Ordovician accretionary complex that subsequently was tectonized during later Paleozoic events (for example, Horton and others, 1989; Muller and others, 1989; Adams and others, 1995; Stewart and others, 1997; Miller and others, 2006). Herein, we refer to it as the Piedmont accretionary complex (fig. 1). It should be noted that unlike generic accretionary complexes, the western Piedmont domain was intruded by magmatic arc plutons during its development (for example, Pavlides and others, 1994; Meschter-McDowell and others, 2002). The distribution of Ordovician thrust sheets with Ordovician peak metamorphism to the east of the Blount foreland basin clastic wedge strongly links the Piedmont accretionary complex to the Taconian demise of the Appalachian margin; some workers have attributed these Taconian events to closure of a Taconic Seaway (Hatcher, 1972; Pavlides, 1981). This scenario implies that the eastern Piedmont domain is of peri-Laurentian origin, an implication generally supported by detrital zircon and Nd isotopic studies (Bream and others, 2004).

It is intriguing to note that the Piedmont accretionary complex of Virginia, contains an unusual Late Ordovician (Wilson, 2001) shoshonitic monzonite to monzogabbro pluton (Pavlides and others, 1994). The only other shoshonitic pluton known in the Appalachian orogen is a Middle Ordovician monzogabbro in the outboard portion of the peri-Laurentian tract in the Dunnage domain of Newfoundland (Lissenberg and others, 2005). There, its shoshonitic nature has been attributed to melt contributions from subcontinental lithospheric mantle during a Middle Ordovician slab break-off event beneath the peri-Laurentian microcontinent (Lissenberg and others, 2005; van Staal and others, 2007). It is tempting to speculate that the Piedmont domain may record a similar event.

The eastern portion of the domain contains substantially more rocks with oceanic and magmatic arc protoliths that tend to define belts such as the central Virginia volcanic plutonic belt (or Chopawamsic belt, here) (Pavlides, 1981), the Chauga belt (Hatcher, 1972), and the Dadeville belt (for example Seal and Kish, 1990) that are more coherent and more laterally continuous than those of the western Piedmont domain. Geochronological studies indicate that suprasubduction zone magmatism was active in this portion of the domain from the Early to Late Ordovician (for example, Seal and Kish, 1990; Horton and others, 1998; Coler and others, 2000). In addition, geochronological and Nd isotopic data indicate that the Chopawamsic arc was constructed on some form of continental crust (Coler and others, 2000). North of the Virginia promontory (fig. 1), Chopawamsic arc volcanic rocks are unconformably overlain by black slate containing Late Ordovician, likely late Caradocian, fossils (Stose and Stose, 1948; Tillman, 1970; age determination on trilobites recently confirmed by W. D. Boyce, personal communication, 2005). The trilobite fauna shows no faunal provinciality (W. D. Boyce, personal communication, 2005). In the same general area as the fossil occurrences, Pb isotopic studies on massive sulphide deposits show that they contain relatively high radiogenic Pb isotopic compositions (Swinden and others, 1988). Collectively, the distinct Caradocian black slate and the high radiogenic Pb isotopic signatures are reminiscent of the eastern Dunnage domain and suggest that the Chopawamsic belt, like the eastern Dunnage domain, may be of peri-Gondwanan affinity. In contrast, detrital zircon and Nd isotopic studies undertaken in the Piedmont domain south of the Virginia promontory suggest that the domain in that area is of peri-Laurentian affinity (Bream and others, 2004). It is a distinct possibility that both lines of reasoning are valid and that the juncture between the two is at the latitude of the Virginia promontory, where possibly the Chopawamsic belt is structurally higher and has been eroded off of the eastern Piedmont domain to the south. The change in metamorphic grade of the eastern Piedmont domain, from greenschist facies in northern Virginia to middle and upper amphibolite facies in the vicinity of the promontory and to the south, lends support to such speculation.

In overview, the Piedmont domain embraces a structurally modified Ordovician accretionary complex with tectonic remnants of Late Cambrian to Late Ordovician suprasubduction zone terranes in its western portion and it contains more coherent, Early Ordovician to Late Ordovician oceanic and magmatic arc assemblages in its eastern portion. In the Piedmont accretionary complex, the presence of Ordovician thrust sheets with Ordovician peak metamorphism and eclogites emplaced onto the Laurentian realm where the coeval, Early to Middle Ordovician, Blountian foreland clastic wedge was deposited provides strong evidence for east-directed subduction and Taconian orogenesis. The arc generated during this event could well be preserved in more eastern portions of the accretionary complex or in the eastern portion of the domain. Exhumation of eclogite was underway in the Middle Ordovician (Miller and others, 2000), indicating that subduction of the Taconic Seaway had likely come to an end by then. Early Ordovician arc intrusions found along the length of the Piedmont accretionary complex lead us to suggest that during the Early Ordovician, there was also westward subduction beneath the Taconian orogenic system (Hibbard, 2000). It is possible that younger magmatic arc rocks in the eastern portion of the domain are also related to this west-directed subduction system. The Piedmont domain may also record the effect of a Late Ordovician slab break-off event, as suggested by the shoshonitic intrusion in Virginia.

*Comparison of Dunnage and Piedmont domains.*—Direct comparison of the northern and southern Iapetan realm is clouded by the large discrepancy in knowledge, as well as a lack of contiguity between the two domains. Whereas detailed tectonic analysis involving models with c. 5 m.y. resolution can be crafted for the Dunnage domain, only relatively broad generalities can be extracted from the Piedmont domain. Nonetheless, first-order similarities between the two domains can be recognized; in particular, both contain oceanic and arc rocks that overlap closely in age. Furthermore, the lithotectonic record of the Piedmont domain contains elements also documented in the western, peri-Laurentian tract of the Dunnage domain, including east-directed subduction and its termination in the Middle Ordovician, west-directed Middle Ordovician subduction beneath the Taconian system, and perhaps Middle to Late Ordovician slab break-off in each domain. Likewise, distinct Late Ordovician black slate and the Pb isotopic signature of massive sulphide deposits in the Chopawamsic belt of the Piedmont domain are diagnostic features of the eastern, peri-Gondwanan part of the Dunnage domain.

Despite these first-order similarities, second-order contrasts exist between the two domains. The Piedmont domain, and particularly the western portion, contains a substantially greater volume of metaclastic rocks than the Dunnage domain. This difference in the volume of metaclastic rocks could be the result of the nature of the Taconic Seaway between Laurentia and the peri-Laurentian microcontinent. It is conceivable that sedimentary supply to the basin may have been greater in the Piedmont domain than in the Dunnage domain. Perhaps the Piedmont block was larger than microcontinental blocks to north, affording a greater exposed surface area to erosion; such a scenario could account for a greater volume of clastic material in the basin and hence a more robust accretionary complex in the Piedmont domain. Another difference is that oceanic and arc rocks in the Piedmont domain display less physical coherency and lateral continuity than those of the Dunnage domain. This apparent difference may be a function of the crustal level now exposed and/or tectonic setting. In the Piedmont domain, perhaps the bulk of the magmatic arcs have been eroded off, leaving only deeper seated roots and portions tectonically dragged to mid/deep crustal depths. In terms of tectonic setting, the western Piedmont domain has been subjected to localized intense Alleghanian shortening that could also contribute to the present patchy distribution of arc material.

Finally, the localized Early Cambrian (c. 530 Ma) thermal event recorded in the Piedmont accretionary complex has no known counterpart in the Dunnage domain; similar ages have been obtained from monazite in the western Dunnage domain just north of the New York promontory, but it is unclear if the rocks yielding the age represent true Iapetan realm rocks or are peri-Gondwanan realm rocks in a structural window (Dietsch and Jercinovic, 2005). In the southern Appalachians this event was initially thought to be related to peri-Gondwanan tectonics, as such an age is common in Gondwanan terranes (Hibbard and others, 2003a); however, recent study indicates that rocks yielding the Early Cambrian age data contain detrital zircon populations indistinguishable from those of nearby Neoproterozoic rocks in the Laurentian realm (Carter and others, 2006), thus consistent with a Laurentian affinity for the Piedmont domain rocks. In light of the lithotectonic history for the Laurentian realm (see above), the Early Cambrian event overlaps in time with the rift-drift transition for the Appalachian margin and formation of a peri-Laurentian microcontinent. It is conceivable that the Early Cambrian thermal event was associated with the breakup and migration of the newly formed microcontinent into Iapetus. Alternatively, it is possible that we do not yet adequately understand the systematics of monazite dating.

Despite these second-order contrasts between the domains, their first order lithotectonic histories correspond in recording closing of a Taconic Seaway along the length of the orogen and apparently a subsequent initiation of westward subduction beneath the modified Laurentian margin. It is unclear if a peri-Gondwanan oceanic tract is preserved in the southern orogen, although the Chopawamsic belt looks to be the best potential candidate.

### *Peri-Gondwanan Realm*

The Appalachian peri-Gondwanan realm encompasses a group of domains along the eastern flank of the orogen that had a Gondwanan heritage prior to their accretion to eastern Laurentia. Within the exposed orogen, the realm contains four major domains, including Ganderia, Avalonia, and Meguma in the north and Carolinia in the south (fig. 1). In the northern Appalachians, Avalonia and Meguma extend in the subsurface to the edge of the modern passive margin (for example, Miller, 1995). In the southern Appalachians, another major peri-Gondwanan block, Suwanee, lies entirely in the subsurface immediately to the south of the exposed orogen; the limited nature of subsurface data beneath the Atlantic coastal plain allows for the potential that other distinct peri-Gondwanan blocks could lie outboard of Carolinia (for example, Dennis and others, 2004). With the exception of Meguma, the exposed peri-Gondwanan blocks record the history of Neoproterozoic Gondwanan magmatic arc systems and their ensuing Paleozoic evolution; Meguma preserves a sedimentary record of sustained Paleozoic quiescence along a passive margin until the latest Early Devonian (for example, Schenk, 1997). It has long been known that Meguma has no known exposed southern Appalachian equivalent (for example, Williams, 1978) and hence will not be discussed below. The detailed lithotectonic history of the peri-Gondwanan realm has recently been presented (Hibbard and others, 2007) and the following is an abridgement of that study

*Ganderia.*—Ganderia (van Staal and others, 1998; Barr and others, 1998) is in both fault and stratigraphic contact with the peri-Gondwanan tract of the Dunnage domain. For example, in central Newfoundland, the contact is marked by a thrust fault that emplaces peri-Gondwanan tract ophiolite on top of Ganderia (Colman-Sadd and others, 1992), whereas in northern Maine and New Brunswick, Dunnage domain volcanic rocks unconformably overlie Ganderia (van Staal and others, 1998). The oldest rocks known in Ganderia are platformal clastic and carbonate units in New Brunswick and Maine, which range in age between 750 Ma to 1230 Ma (White and Barr, 1996; Barr and others, 2003). Younger Ganderian sequences record two main pulses of late Neoproterozoic arc and back arc magmatism; one pulse spanning from c. 630 to 610 Ma and the second pulse starting at c. 570 to 560 Ma and continuing sporadically until c. 525 Ma (for example, White and Barr, 1996; White and others,

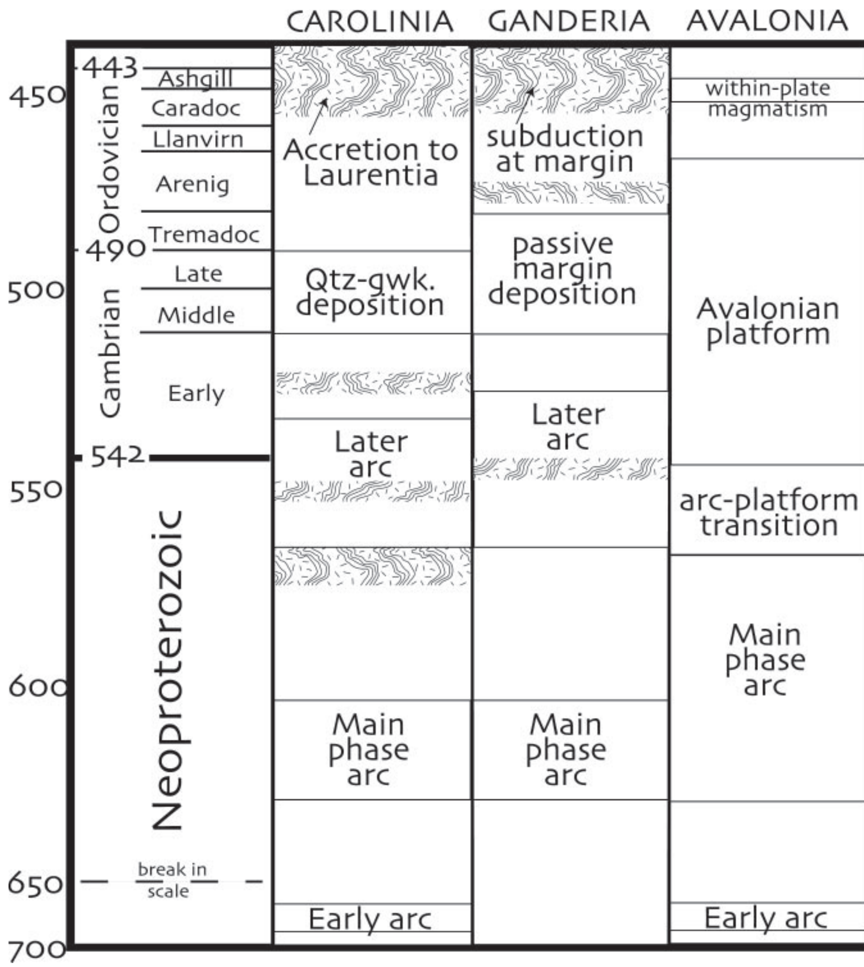


Fig. 4. Comparison of main lithotectonic units that post-date 700 Ma in the peri-Gondwanan domains that record magmatic arc evolution.

2002; Rogers and others, 2006) (fig. 4). In the context of comparing peri-Gondwanan realm crustal blocks, the most significant observation concerning Ganderia is that arc activity continued into the Paleozoic (for example, Barr and others, 2003; Rogers and others, 2006). Late Neoproterozoic-earliest Paleozoic tectonism of these arc rocks has been documented throughout Ganderia (for example, Nance and Dallmeyer, 1994; White and Barr, 1996) although the cause of tectonism is ambiguous. Ganderian arc rocks are succeeded by the hallmark of the domain, a Middle Cambrian-Early Ordovician passive margin sequence of quartzose and feldspathic clastic rocks (for example, van Staal and others, 1996). Ganderia tectonically interacted with the peri-Gondwanan oceanic tract in the Late Cambrian to Early Ordovician (fig. 3) and ultimately it was accreted to Laurentia following Late Ordovician to Early Silurian destruction of the adjacent peri-Gondwanan tract back arc system (van Staal and others, 1996, 1998).

*Avalonia.*—Avalonia is in fault contact with Ganderia along a fault system that is anchored by the Honey Hill-Lake Char fault system in New England and the Dover-Hermitage Bay fault in Newfoundland. The oldest rocks in Avalonia comprise an areally limited, c. 750 Ma oceanic tract in Newfoundland (for example, O'Brien and others, 1996). The earliest arc sequences range in age from c. 670 to c. 685 in Newfoundland and Nova Scotia (Bevier and others, 1993; O'Brien and others, 1996; Barr and others, 1998) (fig. 4). The main pulse of Avalonian arc magmatism spans from c. 635 Ma to c. 570 Ma and was diachronously followed by volcanic and sedimentary rocks recording an extensional regime. Notably, evidence for collision between crustal blocks during the termination of main phase arc magmatism is lacking (Murphy and others, 1999; Nance and others, 2002). This transform regime was succeeded in places by a shallow marine, shale-dominated, transgressive clastic platform sequence that extends, without major tectonic disturbance, into the Silurian (for example, Landing, 1996). Avalon was accreted to Laurentia in the Late Silurian to Early Devonian (for example, Waldron and others, 1996).

*Carolinia.*—Carolinia is in tectonic contact with the Piedmont domain along the central Piedmont shear zone, a late Paleozoic thrust fault system (Hibbard and others, 1998). Originally, this shear zone was considered to represent a suture (Hatcher and Zietz, 1980), that is, the tectonic expression of a collision zone marking the closure of an ocean basin (for example, Howell, 1989, p. 214). However, subsequent work has shown that although it is an important tectonic juncture separating Appalachian realms, it formed long after Carolinia had accreted to the orogen and it telescoped part of the domain over the older suture (Hibbard and others, 1998; Hibbard, 2000). The oldest known magmatism in Carolinia is a low-grade magmatic arc sequence that is intruded by metagranodiorite dated at c. 670 Ma (Coler and Samson, 2000) (fig. 4). Main arc activity in the domain later produced juvenile magmas during a 20 m.y. span starting at c. 633 Ma (Wortman and others, 2000). Subsequently, late Neoproterozoic-early Paleozoic penetrative deformational events were imprinted on Carolinia (Hibbard and Samson, 1995; Dennis and Wright, 1997a; Barker and others, 1998). This late Neoproterozoic event, or series of events, appears to have been associated with an arc-arc collision in the domain (Barker others, 1998; Hibbard and others, 2002) and has been considered to be responsible for the genesis of eclogite in the Charlotte terrane arc (Shervais and others, 2003). Carolinia arc magmatism continued concomitantly with tectonism into at least the Early Cambrian before terminating. Carolinia arc magmatic and associated sedimentary rocks are unconformably overlain by 1 to 2 km of fossiliferous, shallow marine, Middle Cambrian mudstone-quartz graywacke of the Asbill Pond formation (for example, Dennis and Wright, 1997a).

Carolinia experienced low-grade metamorphism and regional southeast-vergent thrusting and folding in the Late Ordovician-Silurian (Sutter and others, 1983; Noel and others, 1988; Offield and others, 1995; Hibbard and others, 2003b). This Late Ordovician to Silurian deformation is attributed to the sinistral oblique subduction of Carolinia beneath Laurentia (Hibbard, 2000; Hibbard and others, 2002, 2003b). Recently, based on U-Pb zircon and monazite ages for peak metamorphism in the Piedmont domain (Dennis and Wright, 1997a, 1997b; reviewed in Merschat and others, 2005) some workers have advocated a younger, Late Devonian-Early Mississippian docking of Carolinia involving subduction of the Laurentian margin beneath the peri-Gondwanan domain (Hatcher, 2002; Merschat and others, 2005). While we acknowledge the existence of a thermal event of this age in the Piedmont domain, we question the tectonic interpretation of the ages, because 1. no associated foreland basin exists in either the Iapetan or Laurentian realms to the west, as would be expected from such a loading event, 2. no magmatism, let alone arc magmatism, is of appropriate age in the purported upper plate of Carolinia; the only magmatism of such age in the southern Appalachians is manifest as small-volume granites in the purported lower plate Piedmont domain, 3. two independent paleomagnetic studies have indicated that Carolinia was at Laurentian latitudes by the early Late Ordovician (Vick and others, 1987; Noel and others, 1988), 4. docking at such a late time requires an additional event/explanation for the Late Ordovician-Silurian low-grade metamorphism and southeast-vergent tectonism of Carolinia, 5. as noted by Dennis and Wright (1997b), little evidence supports a penetrative Late Devonian-earliest Mississippian event in Carolinia. We suggest that viable alternative models may explain this mid-late Paleozoic event, possibly involving strike slip tectonics of an already assembled accretionary margin (for example, Trupe and others, 2003; Dennis, 2005).

*Comparison of Ganderia, Avalonia, and Carolinia.*—Rodgers (1972) first suggested a link between rocks here designated as Avalonia and Carolinia; this correlation has been echoed through the years (for example, Williams, 1978; Williams and Hatcher, 1983) to the point where it is considered almost Appalachian 'gospel'. However, from the collective lithotectonic observations of Carolinia and Avalonia presented above, it is clear that following initial similarities in Neoproterozoic arc sequences, their developmental paths were distinct (fig. 4) (see also Secor and others, 1983). Avalonian arc magmatism was terminated in the late Neoproterozoic without crustal collision and it was succeeded by a transform regime that may have overlapped in time with deposition of an overlying platform sequence. In contrast, Carolinia arc cessation was apparently heralded by a late Neoproterozoic arc-arc collision, after which arc magmatism continued into the Cambrian, on the order of 40 to 50 m.y. after the Avalonian magmatic arc activity had ceased (fig. 4). Subsequently, Avalonia was unblemished by significant tectonothermal activity until the Late Silurian-Early Devonian, whereas Carolinia was subjected to Late Ordovician-Silurian tectonism.

In contrast to the commonly accepted Avalonia-Carolinia correlation, we find multiple first-order lithotectonic similarities between Ganderia and Carolinia. In addition to sharing similar Neoproterozoic magmatic arc histories, they 1. record late Neoproterozoic suprasubduction zone magmatism that continues into the Cambrian; this magmatism was coincident with tectonothermal events that likely involved arc-arc collision in Carolinia, 2. preserve a sequence of Cambrian clastic sedimentary rocks overlying magmatic arc and associated rocks in each block, and 3. record a Late Ordovician-Silurian tectonothermal overprint (fig. 4).

We interpret these observations to indicate that Ganderia and Carolinia occupied the upper plate of an active, late Neoproterozoic convergent plate margin that shut down in the Early Cambrian; in contrast, Avalonia occupied a transform or passive margin during this same time frame. Neoproterozoic to early Paleozoic sequences in both Ganderia and Carolinia were subsequently subjected to Late Ordovician-Silurian tectonothermal remobilization related to the accretion of these blocks to Laurentia; noteworthy, both domains occupied the down-going plate during the final phases of accretion to Laurentia. Avalonia does not record significant tectonism until the Devonian. In light of these observations, it is unlikely that Avalonia and Carolinia are close correlatives; instead, our comparison indicates that Ganderia and Carolinia are more closely related.

However, second-order differences exist between Ganderia and Carolinia; most notably the Nd isotopic data for the domains indicates that Carolinia is markedly more juvenile than the more evolved Ganderia. This divergence likely reflects differences in basements between the two domains, differences that can be accommodated along strike of a single arc system (Hibbard and others, 2007). In addition, Carolinia apparently is not intimately associated with a peri-Gondwanan oceanic tract as is Ganderia. Carolinia borders the Chopawamsic belt, which may represent a peri-Gondwanan oceanic-arc tract, but the contact is marked by the late Paleozoic central Piedmont shear zone.

## SUMMARY AND IMPLICATIONS

Review of the first-order traits of the Laurentian, Iapetan, and peri-Gondwanan realms allows for a comparison of the northern and southern segments of the Appalachian orogen; are they really as different as early subdivisions of the orogen implied? The Laurentian realm formed a remarkably homogeneous template for growth along the full length of the orogen. Collectively, the uniformity of the development of the Appalachian margin and insights into the rift history in Newfoundland, lead to the deduction that the entire margin formed as the result of the formation of a Taconic Seaway, with a microcontinent (or microcontinents) at its leading edge, in the Iapetus Ocean. This seaway was the focal point for the complex development of Iapetan arcs and back arcs forming the west side of the Iapetan realm. In the northern Appalachians, the eastern portion of the realm evolved similar complexities as its mirror-image on the Laurentian side and included the development of an extensive Middle to Late Ordovician Tetagouche-Exploits back arc basin along the Ganderian margin that ultimately closed in the Silurian, marking the end of activity in the Iapetan realm. Evolution of the southern segment of the realm, the Piedmont domain, is less clear but the Chopawamsic belt may be equivalent to the eastern Dunnage domain; however, it remains an open question as to whether a southern peri-Gondwanan Iapetan tract exists.

The peri-Gondwanan domains of Carolinia and Ganderia share similar lithotectonic histories, suggesting that they occupied the same peri-Gondwanan plate margin. The younger part of these histories records the diachronous interaction of the peri-Gondwanan plate with the modified Appalachian margin. Late Ordovician-Silurian sinistral oblique collision of Carolinia in the southern Appalachians was followed by the Silurian sinistral oblique arrival of Ganderia in the north. Later arrivals, the northern Appalachian Avalonia and Meguma domains, have no known southern Appalachian counterparts.

This summary of first-order features as reflected in the lithotectonic histories of Appalachian realms indicates multiple similarities exist between the northern and southern segments. Perhaps the weakest link from this perspective is the correlation of units and events in the Iapetan realm. However, the strong similarities shared by the two segments in both the Laurentian and peri-Gondwanan realms that sandwich the less fully known Iapetan realm, as well as the potential correlations between the Dunnage and Piedmont domains outlined above, compel us to tentatively proffer that the pre-Silurian development of the orogen was to a first approximation, uniform in nature.

This along strike uniformity implies that the life cycle of Iapetus was relatively simple, approximating a classic Wilson cycle. The hypotheses that the conjugate rift margin to Laurentia was Amazonia combined with the possibility that the peri-Gondwanan Ganderia also developed on the margin of Amazonia (although clearly not as a conjugate margin to Laurentia) (for example, van Staal and others, 1996), lend support to this idea. Such relative simplicity may be responsible for the undisturbed, smoothly undulating structural grain of the orogen.

Uniformity of the orogen also implies that any first-order differences developed after the Late Ordovician. For example, the presence of a Silurian magmatic arc system (Barr and others, 2002) in the northern Appalachians and its apparent absence in the south likely indicates that different tectonic processes were operative in each segment of the orogen at that time. This hypothesis is supported by the distribution of Avalonia being limited to the northern Appalachians, suggesting that accretion of Avalonia involved subduction limited to the northern segment of the orogen. Likewise, the limited distribution of Meguma may also reflect heterogeneity in processes along the margin. Such differences that are relatively late in the history of the orogen imply that the oceanic tract trailing Carolinia and Ganderia, the Rheic Ocean, was more complex than Iapetus in that it harbored first-order lateral variations.

Nonetheless, it is important to keep in mind the potential differences in the pre-Silurian histories between the two segments; in particular, we need to be aware of the potential 'wild cards' in correlation such as the Goochland domain, the unknown portions of the Piedmont domain, the possibility that a peri-Gondwanan oceanic tract does not exist in the south, and the potential that critical terranes are buried beneath Alleghanian thrusts in the southern Appalachians. Perhaps the ultimate wild card to consider is the significance of strike-slip tectonics in modifying the amalgamated orogen. Only recently have attempts been extended to determine the potential significance and quantify the strike-slip 'reshuffling' of Appalachian lithotectonic elements (Trupe and others, 2003; Bailey and others, 2004; Bartholomew and Tollo, 2004; Dennis, 2005). Part of the solution to this problem may well lie in the Laurentian template of promontories and embayments; conceivably, if contrasting rheological properties existed between accreting terranes and the Appalachian margin, the promontories may well have acted as restraining and releasing bends in any orogen scale strike-slip system (Hibbard, 2004). Consequently, shortening or extension asymmetrically associated with a promontory provides the potential to quantify the minimum amount of strike-slip motion.

In conclusion, it appears that during the first 100 million years of its development the Appalachian orogen followed a uniform blueprint. As we have likely come to the close of Rodgers' (1982) 'Cocacolazoic era', hopefully this analysis has raised questions worthy of the attention of researchers in the 'Early Cyberzoic'.

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