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Detrital zircon ages and Nd isotopic data from the southern Appalachian crystalline core, Georgia, South Carolina, North Carolina, and Tennessee: New provenance constraints for part of the Laurentian margin

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ABSTRACT

Sedimentary and metasedimentary rocks within the southern Appalachian Blue Ridge and Inner Piedmont contain a valuable record of Late Proterozoic Laurentian margin evolution following the breakup of Rodinia. Paleogeographic reconstructions and increasing amounts of geochronologic and isotopic data limit the derivation of these paragneisses to the Laurentian and/or west Gondwanan craton(s). Southern Appalachian crystalline core paragneiss samples have ε_{Nd} values between –8.5 and –2.0 at the time of deposition and contain abundant 1.1–1.25 Ga zircon cores with Grenville 1.0–1.1 Ga metamorphic rims. Less abundant detrital zircons are pre-Grenvillian: Middle Proterozoic 1.25–1.6 Ga, Early Proterozoic 1.6–2.1 Ga, and Late Archean 2.7–2.9 Ga. Blue Ridge Grenvillian basement has almost identical ε_{Nd} values and displays the same dominant magmatic core and metamorphic rim zircon ages. Based on our data, nonconformable basement-cover relationships, and crustal ages in eastern North America, we contend that the extensive sedimentary packages in the southern Appalachian Blue Ridge and western Inner Piedmont are derived from Laurentia. ε_{Nd} values from Carolina terrane volcanic, plutonic, and volcaniclastic rocks are isotopically less evolved than southern Appalachian paragneisses and Blue Ridge Grenvillian basement, easily separating this composite terrane from the mostly Laurentian terranes to the west. Neoproterozoic and Ordovician, as well as Grenvillian and pre-Grenvillian, zircons in eastern Inner Piedmont paragneisses indicate that these samples were deposited much later and could have been derived entirely from a Panafrican source or possibly a mixture of Panafrican and recycled Laurentian margin assemblages.

Keywords: detrital zircons, southern Appalachians, provenance, Rodinia, Blue Ridge, Inner Piedmont

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INTRODUCTION

The considerable extent of the Grenvillian orogen that assembled Rodinia is confirmed by the widespread distribution of Grenvillian belts on numerous pre-Grenvillian cratonic margins (e.g., Hoffman, 1991). Although the existence and Late Proterozoic breakup of the Rodinian supercontinent are virtually indisputable, many details concerning Laurentian margin evolution remain controversial and problematic. Sedimentary fill in rift basins along the eastern Laurentian margin and western Iapetus ocean was deposited nonconformably on Grenvillian and likely pre-Grenvillian crust that forms pre-Paleozoic basement of the southern Appalachians. In these sedimentary sequences is a record of the rift-to-drift transition (Wehr and Glover, 1985; Simpson and Sundberg, 1987; Williams and Hiscott, 1987; Simpson and Eriksson, 1989; Thomas, 1991) and later overprinting by Paleozoic orogenies. A complex rift history is verified by reconstructions of the margin (e.g., Rast and Kohles, 1986; Bartholomew, 1992), basement-cover sequence relationships (e.g., Hatcher et al., this volume), and polyphase rifting (e.g., Badger and Sinha, 1988; Aleinikoff et al., 1995; Brewer and Thomas, 2000; Cawood et al., 2001). Deposition of extensive rift fill, in places well over 1000 m thick, along most of the southern Laurentian margin was coeval with a latest Neoproterozoic–Early Cambrian rifting event. Continued rifting, accompanied by deposition of drift facies across the margin, facilitated development of a true passive margin. There is general agreement regarding Laurentian derivation of western Blue Ridge rift-to-drift sedimentary packages. The paucity of internal paragneiss isotopic and geochronologic data, combined with the polydeformed and metamorphosed nature of the crystalline core, however, has resulted in characterization of internal high-grade lithotectonic packages as "disrupted" (Horton et al., 1989) and "problematic" (Goldsmith and Secor, 1993) terranes. New detrital zircon U-Pb ages and Sm-Nd data obtained from Blue Ridge and Inner Piedmont metapsammitic and metapelitic samples place previously unavailable limits on the provenance of southern Laurentian margin deposits.

GEOLOGIC SETTING

Appalachian terranes are exposed along the length of the orogen as continuous and discontinuous elongate curvilinear belts from Alabama to Newfoundland (Williams, 1978), and are separated by major, mostly orogen-scale, faults (Fig. 1). Both suspect and exotic accreted terranes of the southern Appalachians contain sedimentary sequences deposited in a variety of settings on a range of basements. Western Blue Ridge rift-facies sedimentary and volcanic rocks, which were unconformably deposited on rifted Grenvillian basement, include the Ocoee Supergroup and the Mount Rogers, Grandfather Mountain, and Mechum River Formations. Widely distributed eastern Blue Ridge–western Inner Piedmont metapsammite-dominated packages (e.g., Tallulah Falls, Ashe, Sandy Springs, and Emuckfaw Formations) were deposited on small Grenvillian continental fragments and possibly on oceanic crust. Paragneisses of the Hayesville–Soque River and Chunky Gal–Shope Fork thrust sheets, herein referred to as the central Blue Ridge, and Dahlonega gold belt were deposited as immature siliciclastic sediments intruded by, deposited on, or possibly intercalated with Ordovician mafic assemblages of oceanic and/or volcanic arc/back-arc affinities (Spell and Norrell, 1990; Berger et al., 2001; Thomas et al., 2001; Settles et al., 2001). The Sauratown Mountains, Grandfather Mountain, and Pine Mountain windows expose several internal Grenvillian basement granitoids and their associated cover sequences (Fig. 1). Basement-cover relationships and lithologic features similar to those found in the western Blue Ridge are documented in the Pine Mountain (e.g., Schamel et al., 1980; Sears et al., 1981; Kish et al., 1985; Steltenpohl, 1992) and Sauratown Mountains (McConnell, 1988; Walker et al., 1989) windows. Ion microprobe zircon U-Pb geochronologic data favor an Amazonian source for cover-sequence samples from the Pine Mountain window (Steltenpohl et al., this volume).

Several crustal fragments of Laurentian affinity formed during rifting; some were preserved as massifs in the southern Appalachian Blue Ridge (e.g., Toxaway dome), while others were transported and ultimately accreted as exotic terranes onto other cratons (Dalla Salda et al., 1992; Dalziel et al., 1994; Keppie et al., 1996; Thomas and Astini, 1996; Cawood et al., 2001). Based on their structural positions within the orogen, southern Appalachian Grenvillian basement massifs can be described as external massifs that were transported in thrust sheets over the Laurentian margin and internal massifs, which are located beneath major detachments and are exposed in windows (Hatcher, 1984). Western Blue Ridge external basement massifs are distributed within the internal portion of the terrane as a linear outcrop belt along the Blue Ridge Front adjacent to the Valley and Ridge and in the Grandfather Mountain window. Eastern Blue Ridge internal massifs are much smaller, occurring mostly as complexly folded structures (Hatcher et al., this volume).

Rift-related magmatic rocks provide constraints on the timing of Rodinian rifting; unfortunately, western Iapetus geochronologic and paleomagnetic data for these rocks are sparse. Data for the southern Appalachians are limited to Neoproterozoic ages ranging from 730 to 760 Ma for the Bakersville dike swarm (Goldberg et al., 1986; Ownby et al., this volume), Crossnore complex plutons (Su et al., 1994), and Mount Rogers metarhyolite (Aleinikoff et al., 1995). Rift-related magmatic rocks in the adjacent central Appalachians, however, include the Catoctin Formation metarhyolite, dated at 572 ± 5 and 564 ± 9 Ma (Aleinikoff et al., 1995), and the Robertson River suite, dated at 702–735 Ma (Tollo and Aleinikoff, 1996). The two age groups for rift-related magmatism in the Appalachians are interpreted to represent an earlier failed event and a younger successful event that created and opened the Iapetus ocean (Badger and Sinha, 1988; Aleinikoff et al., 1995; Brewer and Thomas, 2000). Cawood et al. (2001) also proposed that the younger event is divisible into two distinct phases: the first, ca. 570 Ma, opened the Iapetus ocean, and the second, 540–535 Ma, evolved into a

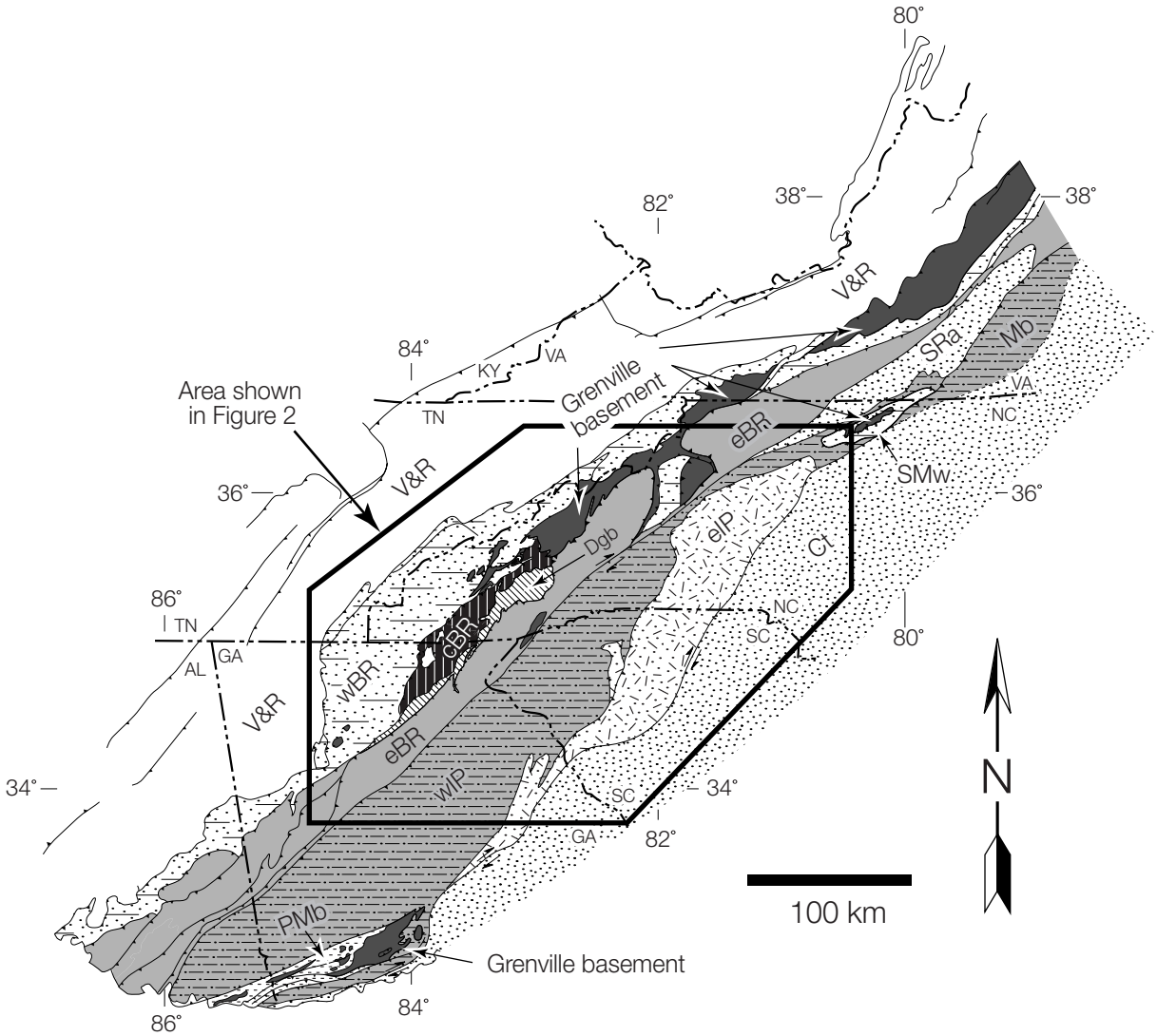

Figure 1. Tectonic map of the southern Appalachians. cBR—central Blue Ridge; Ct—Carolina terrane; Dgb—Dahlonega gold belt; eBR—eastern Blue Ridge; eIP—eastern Inner Piedmont; Mb—Milton belt; PMb—Pine Mountain Block; SMw—Sauratown Mountains window; SRa—Smith River allochthon; V&R—Valley and Ridge; wBR—western Blue Ridge; wIP—western Inner Piedmont. Modified from Hatcher et al. (1990).

true passive margin after fragmentation of much of the southern Laurentian margin, probably again reflecting the rift-to-drift transition (e.g., Wehr and Glover, 1985; Williams and Hiscott, 1987). It was in these complex latest Neoproterozoic to Early Cambrian rift basins, and in nearly coeval to time-transgressive distal slope-rise to ocean floor environments, that paragneisses of the southern Appalachian crystalline core were deposited.

SAMPLES

Samples were collected using several criteria, including quality of mapping and documented tectonic or stratigraphic significance of individual units. Sampling was biased toward metapsammite lithologies that were expected to contain abundant detrital zircons. Fresh unaltered material representative of each unit or lithology was collected. We present new U-Pb detrital zircon ages and Sm-Nd whole-rock isotopic data for 20 metasedimentary samples from the southern Appalachian Blue Ridge and Inner Piedmont. Paleozoic metamorphic grade of these samples ranges from subgreenschist in the westernmost Blue Ridge to middle and upper amphibolite facies in the eastern Blue Ridge and Inner Piedmont (see Figure 2 and Table 1 for sample localities).

Western Blue Ridge Samples

Samples from the western Blue Ridge are from Ocoee Supergroup rift facies. The basal rift facies nonconformably overlie Grenville basement in the western Blue Ridge (King et al., 1958). One sample is from the Snowbird Group, the old-

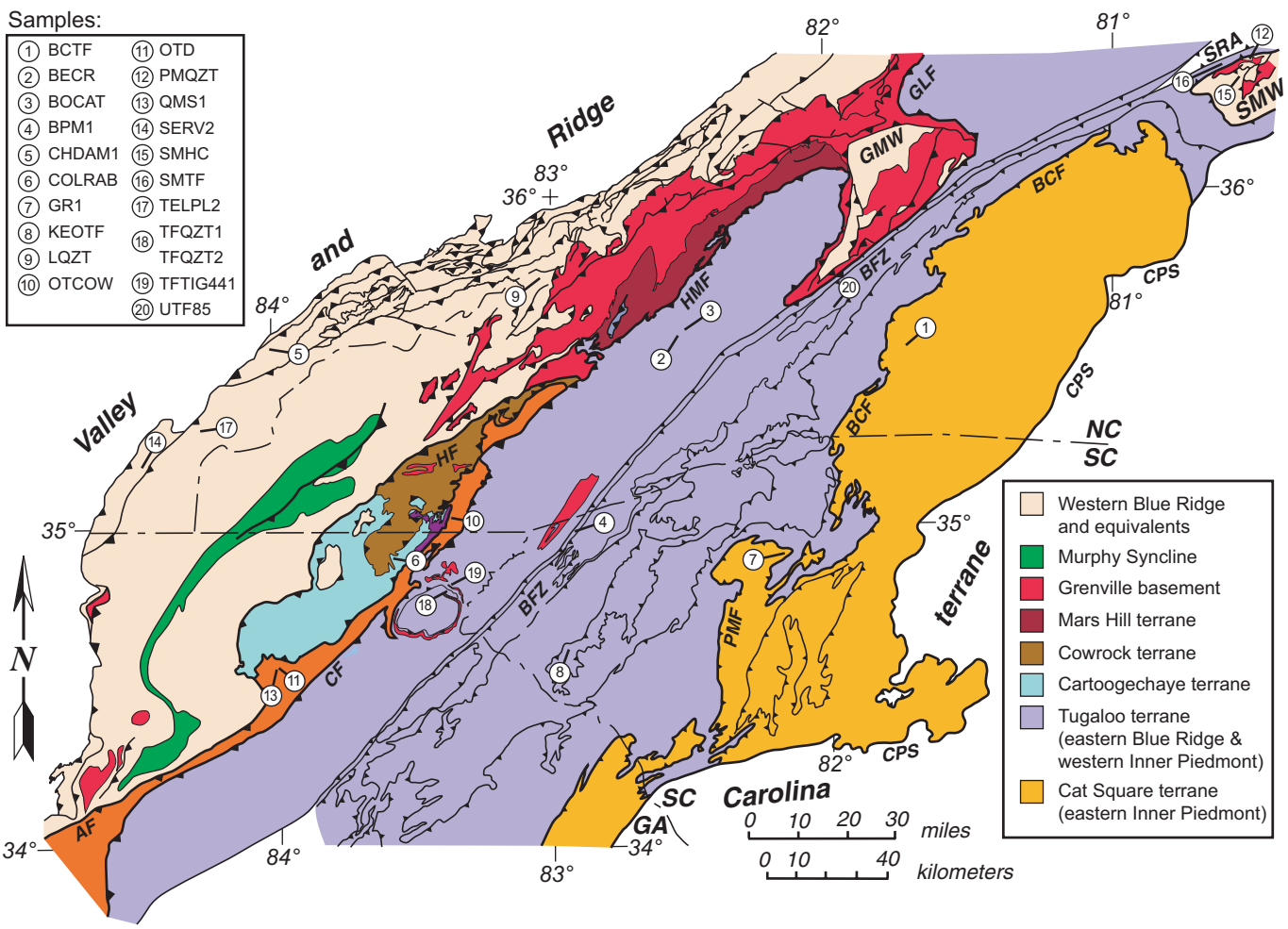

Figure 2. Geologic map of a portion of the southern Appalachians with sample locations. AF—Allatoona fault; BCF—Brindle Creek fault; BFZ—Brevard fault zone; CF—Chattahoochee fault; CPS—Central Piedmont suture; GLF—Gossan Lead fault; GMW—Grandfather Mountain window; HF—Hayesville fault; HMF—Holland Mountain fault; PMF—Paris Mountain fault; SMW—Sauratown Mountains window; SRA—Smith River allochthon. Modified from Hatcher et al. (this volume). Sample abbreviations and labels correspond to those provided in Table 1.

est Ocoee Supergroup unit; one is from the Great Smoky Group; and two are from the Walden Creek Group, the youngest unit in the Ocoee Supergroup. The Longarm Quartzite is predominantly feldspathic sandstone that ranges from <100 to 1,000 m thick in the middle of the Snowbird Group (Montes and Hatcher, 1999). The sample is from the Pigeon River Gorge in North Carolina, collected at the westbound rest area on Interstate 40. Upper Ocoee Supergroup rift samples include a medium- to coarse-grained sandstone sample with small conglomeratic interlayers from the uppermost Dean Formation (Great Smoky Group) on Tennessee 68 southeast of Tellico Plains. Calcareous fine-grained Sandsuck Formation (Walden Creek Group) sandstone was collected in Springtown near Starr Mountain, Tennessee. A matrix-supported polymictic conglomerate from the Sandsuck Formation (Walden Creek Group) was also sampled at Chilhowee Dam on U.S. 129 in southeastern Tennessee. This conglomerate contains large (up to 0.5 m) rounded clasts of mostly milky quartz with subordinate amounts of quartzite, limestone, dolostone, quartz-epidote (from veins), rare granitoid, and black mud (now slate) in a dominantly medium-grained siliciclastic matrix. Attempts were made during sample preparation to isolate matrix material in this sample.

Central Blue Ridge Sample

One sample of central Blue Ridge metasandstone (Coleman River Formation of Hatcher, 1979) was collected on U.S. 76 west of Clayton, Georgia, <1 km east of the Rabun-Towns county line. This unit is the most widely distributed of the Coweeta Group, making up most of the Hayesville–Soque River thrust sheet (Cowrock terrane of Hatcher et al., this volume).

Dahlonega Gold Belt Samples

Three samples were collected from the Otto Formation in the Dahlonega gold belt, a unit consisting of intercalated meta-

TABLE 1. SAMPLES WITH STRATIGRAPHIC ASSOCIATION AND COORDINATES

Sample	Figure 2 location	Formation or unit name	7.5-minute quadrangle	County (state)	Latitude (°N)*	Longitude (°W)*
Western Blue Ridge						
CHDAM1	5	Walden Creek Group (Ocoee Supergroup)	Tallassee	Blount (TN)	35.548	84.050
LQZT	9	Longarm Quartzite, Snowbird Group (Ocoee Supergroup)	Cove Creek Gap	Haywood (NC)	35.702	83.040
SERV2	14	Sandsuck Formation, Walden Creek Group (Ocoee Supergroup)	McFarland	Polk (TN)	35.248	84.444
TELPL2	17	Dean Formation, Great Smoky Group (Ocoee Supergroup)	Tellico Plains	Monroe (TN)	35.336	84.296
Central Blue Ridge						
COLRAB	6	Coleman River Formation	Hightower Bald	Rabun (GA)	34.908	83.612
Dahlonega gold belt						
OTCOW	10	Otto Formation	Prentiss	Macon (NC)	35.060	83.453
OTD	11	Otto Formation	Campbell Mountain	Lumpkin (GA)	34.560	84.074
QMS1	13	Otto Formation	Campbell Mountain	Lumpkin (GA)	34.533	84.018
Eastern Blue Ridge						
BECR	2	Tallulah Falls Formation–Ashe Formation (metagraywacke member)	Dunsmore Mountain	Buncombe (NC)	35.454	82.661
BOCAT	3	Tallulah Falls Formation–Ashe Formation (metagraywacke member)	Asheville	Buncombe (NC)	35.600	82.538
TFQZT1	18	Tallulah Falls Formation (quartzite member)	Tiger	Rabun (GA)	34.817	83.424
TFQZT2	18	Tallulah Falls Formation (quartzite member)	Tallulah Falls	Rabun (GA)	34.736	83.391
TFTIG441	19	Tallulah Falls Formation–Ashe Formation (metagraywacke member)	Tiger	Rabun (GA)	34.838	83.422
Sauratown Mountains window						
SMHC	15	Hogan Creek Formation	Siloam	Surry (NC)	36.271	80.602
PMQZT	12	Pilot Mountain Quartzite	Pinnacle	Surry (NC)	36.344	80.482
Western Inner Piedmont						
BPM1	4	Chauga River Formation (Brevard–Poor Mountain Transitional member)	Salem	Oconee (SC)	34.916	82.914
KEOTF	8	Tallulah Falls Formation–Ashe Formation (aluminous schist member)	Seneca	Oconee (SC)	34.696	82.879
SMTF	16	Tallulah Falls Formation–Ashe Formation (metagraywacke member)	Copeland	Surry (NC)	36.275	80.732
UTF85	20	Tallulah Falls Formation–Ashe Formation (metagraywacke member)	Marion East	McDowell (NC)	35.644	81.987
Eastern Inner Piedmont						
BCTF	1	Metagraywacke biotite-gneiss not presently assigned to a formation	Benn Knob	Rutherford (NC)	35.539	81.702
GR1	7	Metagraywacke biotite-gneiss not presently assigned to a formation	Greer	Spartanburg (SC)	34.917	82.139

*Coordinates are North American Datum 1927–Continental United States (NAD27 CONUS).

pelite and metasandstone (Hatcher, 1988). One sample locality is within Coweeta Hydrologic Laboratory property near Otto, North Carolina, in the footwall of the Shope Fork thrust. Two samples are from the Allatoona thrust sheet in the footwall of the Hayesville–Soque River thrust fault, ~2.5 km west and ~7 km west-northwest of Dahlonega, Georgia, in the Campbell Mountain 7.5-minute quadrangle.

Eastern Blue Ridge and Western Inner Piedmont Samples

Six samples of Tallulah Falls–Ashe Formation were collected from the eastern Blue Ridge and western Inner Piedmont (Tugaloo terrane of Hatcher et al., this volume). The eastern Blue Ridge Tallulah Falls–Ashe Formation was sampled at a roadcut through Beaucatcher Mountain in Asheville, North Carolina; at a site ~200 m north of Bent Creek Gap in the Bent Creek Experimental Forest ~15 km southwest of Asheville, North Carolina, on the Blue Ridge Parkway (the same locality as sample ts-500 of Merschat and Carter, 2002); and on the north flank of the Tallulah Falls dome on U.S. 23–441 ~5 km south-southwest of Clayton, Georgia. The western Inner Piedmont Tallulah Falls–Ashe Formation was sampled in the Forbush thrust sheet (Heyn, 1984) in a railroad cut in the Yadkin River directly southwest of the Sauratown Mountains window, ~13 km east-northeast of Elkin-Jonesville, North Carolina. A second western Inner Piedmont sample was collected from a roadcut 150 m north of Exit 85 on Interstate 40 south of Marion, North Carolina. A third sample was collected on U.S. 76–123 in the Six Mile thrust sheet at Keowee, South Carolina. All of these samples contain middle to upper amphibolite-facies mineral assemblages and are dominantly one-mica (biotite up to 30%), one-feldspar (plagioclase) metagraywackes. Eastern Blue Ridge Tallulah Falls Quartzite was sampled on U.S. 23–441 at Wiley, Georgia; this sample is medium-grained, locally conglomeratic (vein quartz and both plagioclase and K-feldspar clasts) quartzite located within the Tallulah Falls dome, and at this locality contains upright graded beds (Fritz et al., 1989). The locality of the remaining sample, from the Brevard–Poor Mountain transitional member of Hatcher's (1969) Chauga River Formation, is on the west side of South Carolina 11 where it crosses Lake Keowee, in the westernmost Inner Piedmont (Hatcher and Acker, 1984). This sample consists of metasiltstone with mica-fish and thin metagraywacke interlayers.

Sauratown Mountains Window Samples

Both the Hogan Creek Formation and Pilot Mountain Quartzite were sampled in the Sauratown Mountains window. The Hogan Creek Formation consists of metasandstone, pelitic schist, and minor marble in nonconformable contact with Grenville basement orthogneisses of the outer window (Hatcher et al., 1988). The sample is from an abandoned quarry on the Yadkin River ~4 km upstream from Siloam, North Carolina. Pilot Mountain Quartzite overlies the Sauratown Formation, informally named by McConnell (1988) and formally named by Horton and McConnell (1991), and is also in nonconformable contact with Grenville basement. The Pilot Mountain Quartzite is a well-sorted quartz arenite that contains primary sedimentary structures (Walker et al., 1989). The Pilot Mountain Quartzite and Sauratown Formation are restricted to the inner Sauratown Mountains window.

Eastern Inner Piedmont Samples

The eastern Inner Piedmont samples are metagraywackes from mappable lithologic units not currently assigned to a recognized stratigraphy contained within a metapelite-dominated assemblage (Hatcher and Bream, 2002). One sample was collected ~9 km west-northwest of Casar, North Carolina, in Brier Creek, and the other sample was collected ~2.5 km south of Duncan, South Carolina, near the Duncan Correctional Center.

ANALYTICAL METHODS

Some 4–5 kg of each sample were collected for whole-rock Sm-Nd isotopic analyses and detrital zircon separation. Whole-rock powders were prepared from smaller fractions of representative sample material. Samples were cut into thin slabs on a trim saw, rinsed with isopropyl alcohol and deionized water, broken up by hand, and then ground to a fine powder in an alumina ceramic mill. Sm and Nd isotopic data were determined at the Department of Geological Sciences, University of North Carolina at Chapel Hill, with a Micromass VG Sector 54 thermal ionization mass spectrometer using the same analytical technique as outlined in Fullagar et al. (1997).

Standard mineral separation techniques were employed to isolate heavy nonferromagnetic phases. Attempts to split samples into coarse- and fine-grained fractions were made difficult by overall sample hardness; consequently, separates from the coarser-grained western Blue Ridge Sandsuck Formation conglomerate were obtained from a mixture of clast and matrix fragments despite efforts to sample matrix. A minimum of 60–70 zircon grains per sample were hand-picked, mounted in epoxy with zircon standard AS3 or AS57 (1099 Ma; Paces and Miller, 1993) and/or R33 (419 Ma; Stanford University–U.S. Geological Survey Micro Analysis Center), and polished to the approximate center of average-size grains. Zoning and inclusions were identified from cathodoluminescence (CL) images obtained for each grain, and in most cases grains were also photographed with a combination of transmitted and reflected light to augment surface and internal feature identification. Sensitive high-resolution ion microprobe (IMP) data were collected during two sessions at the University of California at Los Angeles (UCLA) using the Cameca IMS-1270 and during four sessions at Stanford University using the SHRIMP-RG (sensitive high-resolution ion microprobe reverse geometry) over two years.

Routine analytical techniques and operating conditions for IMP zircon analyses were followed (e.g., Quidelleur et al., 1997,

for the Cameca IMS-1270 technique; Bacon et al., 2000, for the SHRIMP-RG technique) and are briefly summarized here. The primary ion beam produced analytical pits ~1 μm deep and up to ~25 μm by ~30 μm wide (smaller beam sizes, down to ~10 μm, were used for some UCLA data). Before each analysis, the primary beam was used to remove the gold coat and surface contamination on the targeted spot. IMP sessions at UCLA employed fifteen mass peak scans for each spot. The number of scans was reduced to five, with only a slight decrease in precision due in part to a larger primary beam, for the Stanford IMP sessions to increase the total number of analyses per sample. Sample isotopic counts were referenced to counts on a zircon standard (AS3 or AS57; R33 was also used during some Stanford sessions), which was analyzed after approximately every four to six unknown analyses. Most unknown analyses contained minor amounts of common Pb corresponding to modest common Pb corrections. All analyses were corrected for common Pb using a ^{204}Pb correction. Analyzed grains were reimaged (via backscattered electron and CL imaging) with a Cameca SX-50 electron microprobe at the University of Tennessee–Knoxville to confirm the location and dimensions of IMP analytical spots (Fig. 3).

Analyses with ^{206}Pb*/^{238}U and ^{207}Pb*/^{206}Pb* ages (Pb* denotes radiogenic Pb) that differed by more than 10% were excluded from probability plots in order to increase the likelihood that summed probabilities represent accurate ages; similar studies used comparable values (e.g., Mueller et al., 1992; Cawood and Nemchin, 2001; DeGraff-Surpless et al., 2002). We excluded Paleozoic rim data and constructed summed probability plots of remaining core and non-Paleozoic rim data using ^{206}Pb*/^{238}U ages for analyses <1.6 Ga and ^{207}Pb*/^{206}Pb* ages for analyses >1.6 Ga. For reference, probability curves for all data using ^{207}Pb*/^{206}Pb* ages (normally discordant and ^{207}Pb*/^{206}Pb* ages >800 Ma concordant) and ^{206}Pb*/^{238}U ages (reversely discordant and ^{207}Pb*/^{206}Pb* ages <800 Ma) are provided.

As expected due to the reduced sensitivity of ^{207}Pb*/^{206}Pb* ages for young zircons, most analyses excluded were Late Proterozoic and Paleozoic, although a Middle Proterozoic component with >10% age discrepancies was noted in several samples. The choice of 1.6 Ga was arbitrary (e.g., Cawood and Nemchin, 2001, selected 1.5 Ga), but convenient because of the small number of analyses at or near this age. Statistically, some zircon age ranges within individual samples possibly were not identified (Dodson et al., 1988); therefore our data are better suited for evaluation based on positive rather than negative results (i.e., the presence of an age is more reliable than its absence). Nonetheless, the absence of key zircon ages has significant importance with regard to the dominant source or sources of our samples. Data were pooled into summed probability plots for each tectonic division sampled.

RESULTS

The goal of this research was to address provenance constraints based on new detrital zircon ages and Nd isotopic data for samples from each of the major southern Appalachian tectonic divisions west of the central Piedmont suture and southeast of the Blue Ridge front (Figs. 1 and 2). Isotopic and geochronologic data for metasedimentary rocks must be interpreted together with structural and stratigraphic constraints provided by field observations and detailed mapping. Despite a number of published detrital heavy mineral suite studies (e.g., Carroll et al., 1957; Hadley, 1970), isotopic and geochronologic studies similar to our own in the southern Appalachians are

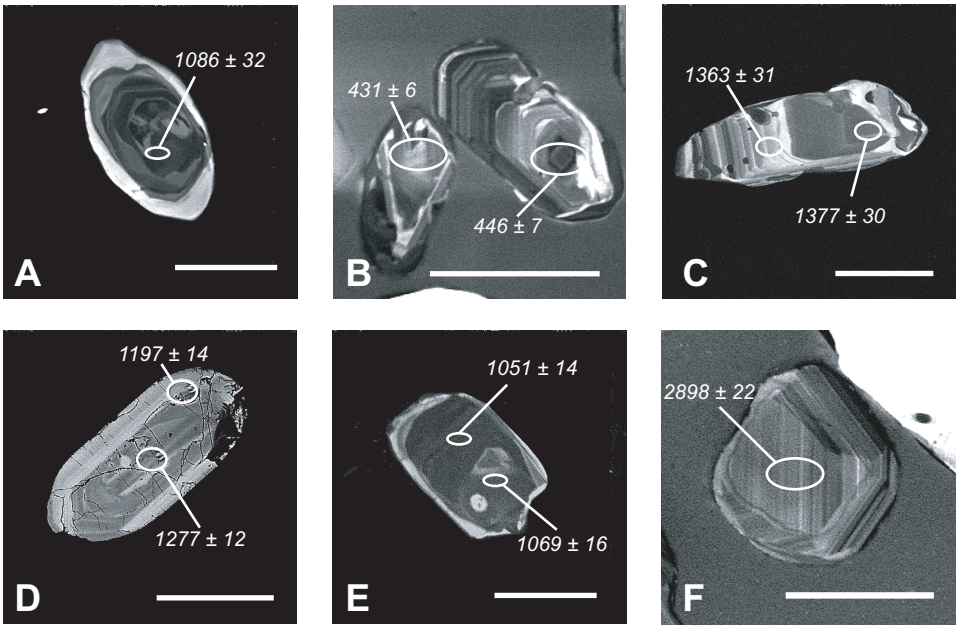

Figure 3. Cathodoluminescence (CL) and backscattered electron (BSE) images of analyzed detrital zircons. Unless otherwise noted, ages are ^{207}Pb*/^{206}Pb* in Ma with 1σ errors. (A) Eastern Blue Ridge Tallulah Falls sample (CL; sample TFTIG441). (B) Eastern Inner Piedmont metagraywacke (CL; sample GR1). (C) Tallulah Falls Formation (CL; sample SMTF). (D) Sauratown Mountains window Hogan Creek Formation (BSE; sample SMHC). (E) Western Inner Piedmont Tallulah Falls Formation (CL; sample UTF85). (F) Dahlonega gold belt Otto Formation (CL; sample QMS1). Note: Spot locations for B and F are approximate. Scale bar is 100 μm.

sparse. Our results necessitate reevaluation of the provenance and crustal affinity of the terranes from which our samples were collected.

Whole-Rock Sm-Nd Data

Modest but increasing Nd isotopic data now exist for crystalline rocks (mainly granitoids) of the Blue Ridge, Inner Piedmont, and Carolina terrane (Fig. 4). Data from metasedimentary rocks of the Blue Ridge and Inner Piedmont (Table 2) yield depleted mantle model (T_{DM}) ages of 1.2–1.9 Ga and ε_{Nd} values from around the time of deposition (~600 Ma) between –2.1 and –8.5, clearly overlapping the Grenville basement data of Carrigan et al. (2003) and Hatcher et al. (this volume). Our data also partially overlap the field defined for samples from the older, more isotopically evolved Mars Hill terrane (Bartholomew and Lewis, 1988, 1992; Carrigan et al., 2003; Ownby et al., this volume). There appears to be little correlation of isotopic maturity with terrane or distance from the Laurentian margin, but notably the oldest T_{DM} ages are from the Sauratown Mountains window and the Dahlonega gold belt.

Based on these data, these rocks could have been derived from a combination of more isotopically evolved (relative to Grenville basement exposed in the southern Appalachians) source(s) and less evolved juvenile crustal source(s), or, more likely, derived directly from rocks of similar age and isotopic maturity to Grenville basement of the Blue Ridge and Sauratown Mountains window. Data from para- and orthogneisses (Wortman et al., 1996; Coler et al., 2000) of the Chopawamsic and Milton terranes also overlap the field for southern Appalachian Grenville basement, whereas Nd data (mostly metaigneous) from the Kings Mountain, Charlotte, Milton, Carolina slate, Raleigh, Kiokee, and eastern slate belts of the Carolina terrane favor generation of Paleozoic magmas from juvenile, isotopically depleted crust with a minor contribution (possibly increasing with time) from older, more evolved crust

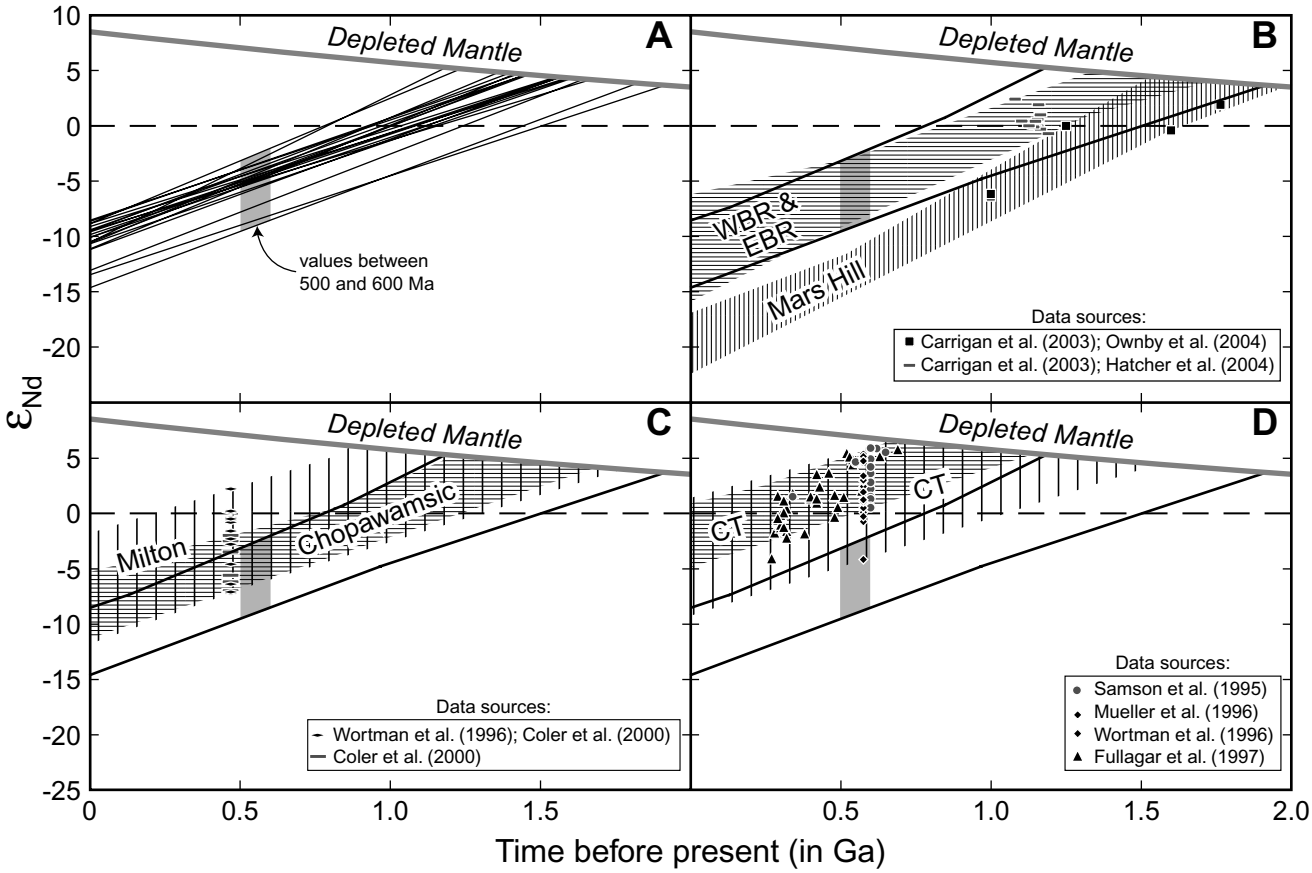

Figure 4. Epsilon Nd evolution over time for metasedimentary samples compared with Blue Ridge basement, Chopawamsic and Milton terranes, and Carolina terrane data. (A) Metasedimentary sample data showing evolution from present to intersection with the depleted mantle. The field outlined is the range of values between 500 and 600 Ma. (B) Metasedimentary data field with data from western and eastern Blue Ridge Grenvillian basement (WBR and EBR; horizontal lines) and Mars Hill terrane (vertical lines). (C) Metasedimentary data field compared with Chopawamsic belt (horizontal lines) and Milton belt (vertical lines) data. (D) Metasedimentary data field compared with Carolina terrane data (CT). Note that the evolution lines in B–D are defined by upper and lower boundaries of data in A, and the symbols represent values at the estimated time of crystallization and/or deposition; data with $^{147}Sm/^{144}Nd > 0.15$ were excluded. Depleted mantle curve from DePaolo (1981).

TABLE 2. SM-ND ISOTOPIC DATA

Sample	Figure 2 location	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$ ($\pm 2\sigma$)†	ε_{Nd} (at present)	ε_{Nd} (at 600 Ma)	T_{DM} (Ga)
Western Blue Ridge								
CHDAM1	5	3.82	21.92	0.10775	0.512093 (04)	–10.6	–3.8	1.37
LQZT	9	3.30	18.71	0.10914	0.512067 (10)	–11.1	–4.4	1.42
SERV2	14	5.66	29.72	0.11783	0.512120 (05)	–10.1	–4.1	1.46
TELPL2	17	7.46	39.57	0.11668	0.512150 (05)	–9.5	–3.4	1.40
Central Blue Ridge								
COLRAB	6	5.41	26.57	0.12594	0.512121 (05)	–10.1	–4.7	1.60
Dahlonega gold belt								
OTCOW	10	8.93	44.75	0.12356	0.512195 (06)	–8.6	–3.0	1.43
OTD	11	7.62	37.48	0.12575	0.512200 (05)	–8.5	–3.1	1.46
QMS1	13	4.30	21.03	0.12660	0.511948 (03)	–13.5	–8.1	1.91
Eastern Blue Ridge								
BECR	2	9.63	47.07	0.12665	0.512146 (06)	–9.6	–4.2	1.57
BOCAT	3	5.14	24.38	0.13050	0.512171 (04)	–9.1	–4.0	1.59
SMTF	16	10.52	52.66	0.12370	0.512091 (07)	–10.7	–5.1	1.61
TFQZT1	18	9.70	55.61	0.10795	0.512184 (03)	–8.9	–2.1	1.24
TFQZT2	18	3.68	19.79	0.11505	0.512100 (07)	–10.5	–4.2	1.45
Sauratown Mountains window								
SMHC	15	4.46	23.55	0.11720	0.511888 (06)	–14.6	–8.5	1.82
PMQZT	12	5.21	27.18	0.11854	0.512064 (06)	–11.2	–5.2	1.56
Western Inner Piedmont								
BPM1	4	8.37	41.23	0.12570	0.512134 (07)	–9.8	–4.4	1.57
KEOTF	8	8.38	39.95	0.12986	0.512185 (05)	–8.8	–3.7	1.56
TFTIG441	19	6.92	32.29	0.13260	0.512152 (05)	–9.5	–4.6	1.67
UTF85	20	11.40	58.35	0.12092	0.512155 (05)	–9.4	–3.6	1.46
Central Inner Piedmont								
BCTF	1	4.80	32.12	0.09238	0.512097 (04)	–10.6	–2.6	1.19
GR1	7	6.73	36.45	0.11430	0.511968 (05)	–13.1	–6.8	1.64

Notes: T_{DM} age calculated according to DePaolo (1981), using $^{147}Sm/^{144}Nd = 0.1967$ and $^{143}Nd/^{144}Nd = 0.512638$ for present-day bulk earth values.

$\varepsilon_{Nd} = [\{^{143}Nd/^{144}Nd]_{Sample} - [^{143}Nd/^{144}Nd]_{Bulk\ earth}\}/\{[^{143}Nd/^{144}Nd]_{Bulk\ earth}\} \times 10^4$. Bulk earth: $^{143}Nd/^{144}Nd = 0.512638$ present day, $^{143}Nd/^{144}Nd = 0.511864$ at 600 Ma.

$^{143}Nd/^{144}Nd$ measured ratios normalized to $^{146}Nd/^{144}Nd = 0.7219$.

†2σ errors are reported as the last two significant digits.

(Fig. 4; Samson et al., 1995; Mueller et al., 1996; Fullagar et al., 1997). Late Proterozoic sources, increasing with distance from the western-eastern Blue Ridge boundary, are noted for Paleozoic granitoids of the southern Appalachian Blue Ridge, Inner Piedmont, and the Carolina terrane (Fullagar et al., 1997); this relationship suggests that magma generation during Paleozoic orogenesis involved larger amounts of juvenile crust away from the Laurentian margin (Fullagar, 2002).

Detrital Zircon Data

Ion microprobe analytical results for this study (Table DR1) are available as GSA Data Repository item 2004022.[1] Summed probabilities for pooled samples (Fig. 5) should be viewed as "relative" abundances because of differences in number and types of samples, number of individual analyses for each division, separation and analytical bias, multiple analyses of grains with unique ages, and consolidation of samples into their respective tectonic terranes. Most detrital grains contain brightly luminescent (in CL) interior zones with oscillatory zoning and relatively unzoned thin darker rims (Fig. 3). Summed probability plots illustrate the abundance of Grenvillian magmatic (1000–1250 Ma) and metamorphic (950–1000 Ma) detrital zircon ages in our samples. Pre-Grenvillian components are also present in all summed probability plots for southern Appalachian crystalline core terranes. Recognized pre-Grenvillian ages are early Middle Proterozoic (1.25–1.6 Ga), Early Proterozoic (1.6–2.1 Ga), and Late Archean (2.7–2.9 Ga). Absence of grains between 2.0 and 2.6 Ga was noted in almost all samples. Except for the eastern Blue Ridge and Sauratown Mountains window, Early Proterozoic zircons occur in each of the terranes. Late Archean zircons were identified in the central Blue Ridge, Dahlonega gold belt, and eastern Inner Piedmont samples.

[1]GSA Data Repository Item 2004022, Table DR1, Ion Microprobe U-Pb Data for Southern Appalachian Detrital Zircons, is available on request from Documents Secretary, GSA, P.O. Box 9140, Boulder, CO 80301-9140, USA, editing@geosociety.org, or at www.geosociety.org/pubs/ft2004.htm.

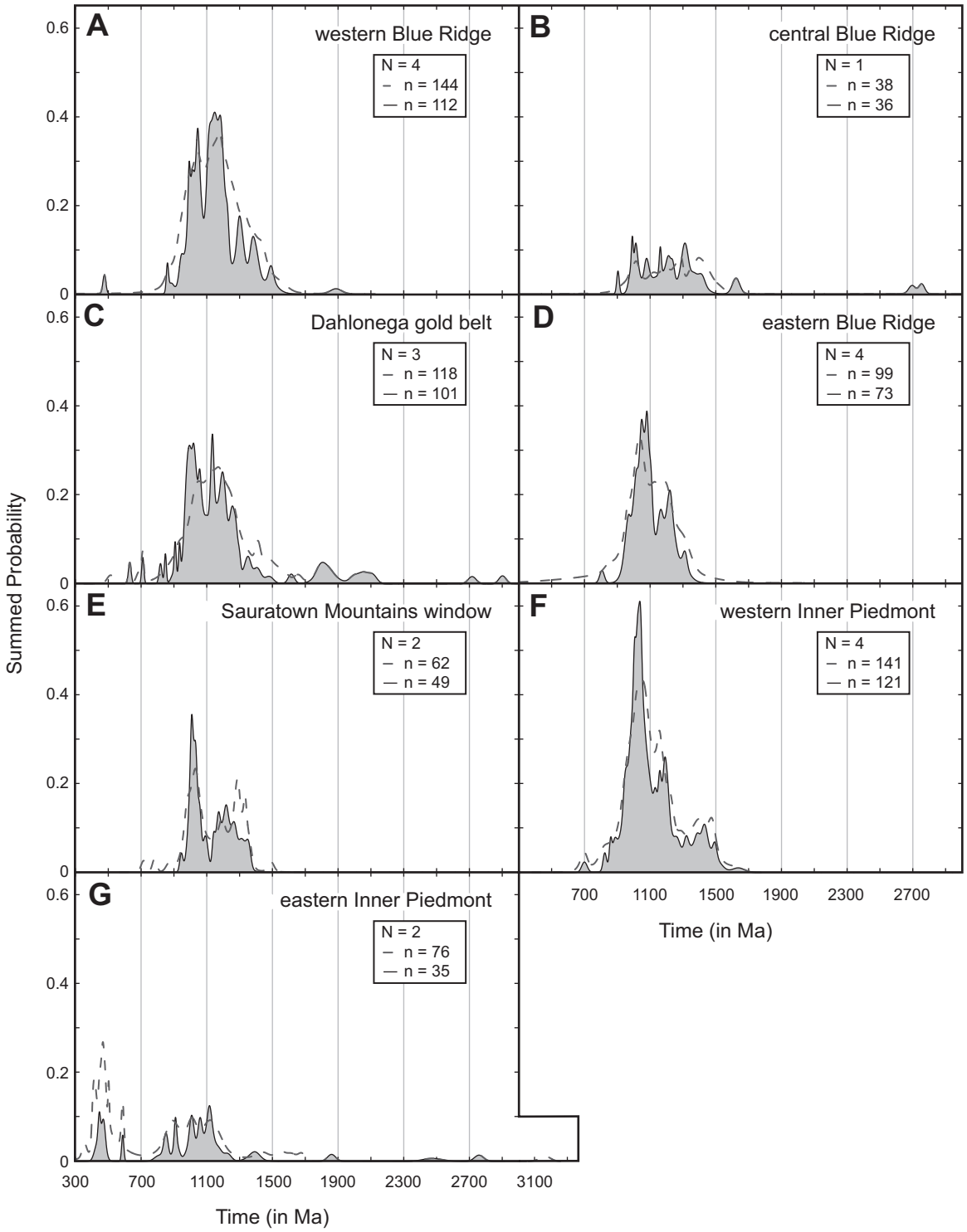

Figure 5. Summed probability plots for detrital zircon data. For reference, probability curves (dashed thicker gray lines) for all the data using $^{207}Pb^{*}/^{206}Pb^{*}$ ages (normally discordant and $^{207}Pb^{*}/^{206}Pb^{*}$ ages greater than 800 Ma concordant) and $^{206}Pb^{*}/^{238}U$ ages (reversely discordant and $^{207}Pb^{*}/^{206}Pb^{*}$ ages less than 800 Ma) are provided. The thinner black lines bounding the shaded areas represent the summed probability of data with $^{206}Pb^{*}/^{238}U$ and $^{207}Pb^{*}/^{206}Pb^{*}$ ages that differ by less than 10%, $^{206}Pb^{*}/^{238}U$ ages for analyses with $^{207}Pb^{*}/^{206}Pb^{*}$ ages <1.6 Ga, and $^{207}Pb^{*}/^{206}Pb^{*}$ ages for analyses with $^{207}Pb^{*}/^{206}Pb^{*}$ ages >1.6 Ga. (A) Western Blue Ridge samples. (B) Central Blue Ridge samples. (C) Dahlonega gold belt samples. (D) Eastern Blue Ridge samples. (E) Sauratown Mountains window samples. (F) Western Inner Piedmont samples. (G) Eastern Inner Piedmont samples. Note that *N* refers to the number of samples from each terrane, *n* refers to the number of analyses plotted, and all plots are at the same scale.

Post-Grenvillian detrital zircons are also present in samples from the Dahlonega gold belt, eastern Blue Ridge, western Inner Piedmont, and eastern Inner Piedmont. These ages are Late Proterozoic and early Paleozoic (eastern Inner Piedmont only) for detrital components.

APPALACHIAN CRUSTAL AFFINITY

Determining crustal affinities for basement and unmetamorphosed, often fossiliferous, sedimentary rocks is more straightforward than clearly identifying crustal affinity for penetratively deformed and metamorphosed sedimentary rocks, such as those found in the southern Appalachian crystalline core. Rifting of the Rodinian supercontinent created numerous crustal fragments and an array of complex depositional basins between the Laurentian and South American cratons (Fig. 6). Evidence exists within the southern Appalachian crystalline core for both exotic (relative to Laurentia) and Laurentian sediment sources. The predominance of 1.0–1.25 Ga detrital zircon ages from the southern Appalachian crystalline core inboard of the Carolina terrane strongly suggests that these basins were all near a Grenvillian source, consistent with the nonconformable nature of most basement-cover contacts in the Blue Ridge and in the Sauratown Mountains window. These Grenvillian ages, however, have limited use when used alone for establishing distinct source(s) because of the nearly ubiquitous presence of Grenvillian belts on the margins of pre-Grenvillian cratons that were near or adjacent to the Laurentian margin during initial rifting stages (e.g., Hoffman, 1991; Rogers, 1996; Dalziel, 1997).

Gondwanan Connections

Early workers positioned the West African craton near or adjacent to the Appalachian segment of Laurentia prior to the breakup of Rodinia (Bird and Dewey, 1970; Hatcher, 1978). More recent work presented convincing evidence that the west Gondwanan cratons of South America (Amazonia and Rio de la Plata) were juxtaposed with the southeastern Laurentian margin (e.g., Dalziel, 1991; Hoffman, 1991; Dalziel, 1997). Exact positions and relative movements of the west Gondwanan Amazonia, Rio de la Plata, Congo, and Kalahari cratons relative to Laurentia are variably portrayed in different paleogeographic reconstructions. In most reconstructions, however, the Amazonia and Rio de la Plata cratons appear as the conjugate margin to Laurentia (e.g., Hoffman, 1991; Dalziel, 1992, 1997; Cawood et al., 2001; Payolla et al., 2002). The Congo craton was also placed opposite the Amazonia craton near the southern Laurentian margin (Hoffman, 1991). Dalziel et al. (2000) suggested that the Kalahari craton may have been close, but still distal, to central Texas at ~1100 Ma. Each of these cratons thus represents a potential source for distal Late Proterozoic to early Paleozoic sediments of the eastern Blue Ridge and Inner Piedmont. The Argentine Precordillera and adjacent Sierra de Pie de Palo is generally accepted as a transported Laurentian fragment (e.g., Borrello, 1971; Ramos et al., 1986; Astini et al., 1995; Ramos et al., 1998; Vujovich and Kay, 1998; Thomas and Astini, 1999; Casquet et al., 2001); other candidates for transported Laurentian fragments include the South American Chilenia and Cuyania terranes, Oaxacan terrane of Mexico, and possibly the Dashwoods block in the northern Appalachians (e.g., Keppie and Ortega-Gutiérrez, 1999; Keppie and Ramos, 1999; Cawood et al., 2001). Paleozoic transfer of peri-Gondwanan terranes (e.g., the Avalonian-Carolina terrane) onto the Laurentian margin is also widely documented (e.g., Secor et al., 1983; Hatcher, 1989; Keppie and Ramos, 1999). Although the exact provenance of these smaller far-traveled crustal fragments is debatable, their present-day distribution is evidence for complex rifting and subsequent plate interactions at the Laurentian margin.

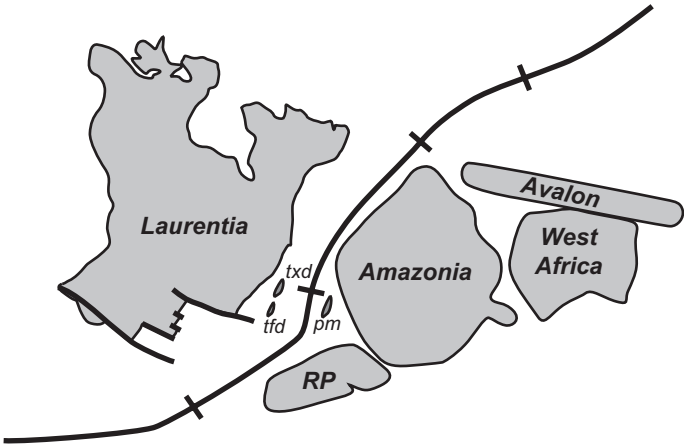

Figure 6. Paleogeography following successful rifting of Rodinia. Modified from Cawood et al. (2001) and Karlstrom et al. (2001). RP—Rio de la Plata craton; txd—Toxaway dome; tfd—Tallulah Falls dome; pm—Pine Mountain block. Compare with Hatcher et al. (this volume), their Figure 14.

An exotic origin for internal, eastern Laurentian terranes (e.g., the Jefferson terrane of Horton et al., 1989) is frequently proposed to model subduction and accretionary wedge development at the margin (e.g., Abbott and Raymond, 1984; Rankin et al., 1989). In such models, rocks in the ultramafic and metamorphosed basalt/gabbro-bearing wedge(s) are considered exotic and are separated from the Laurentian margin by a series of Paleozoic faults interpreted to represent the suture and subduction zone locus (e.g., Hatcher, 1978, 1987; Rankin, 1994). Based on correlations with the Late Proterozoic–Cambrian Potomac orogeny in the central Appalachians, Hibbard and Samson (1995) proposed that portions of the southern Appalachians record tectonothermal histories that predate Laurentian passive margin development, possibly having developed in a peri-Gondwanan setting. Correlation of magmatic and tectonic events was also used to link the Laurentian margin with South America (Dalla Salda et al., 1992; Keppie and Ramos, 1999; Hibbard et al., 2003). In particular, comparisons of the Pampean (530–510 Ma), Famatinian (490–470 Ma), and

Achalian (403–382 Ma) magmatic pulses in the southern Sierras Pampeanas (Argentina) revealed similarities to Laurentian margin magmatic activity, thus supporting the possibility that Laurentia and western Gondwana collided ~470 Ma, producing magmas along the margins of both cratons (Stuart-Smith et al., 1999). This latter possibility would then require that subsequent Paleozoic orogenies (late Taconian, Acadian, and Alleghanian) were intracratonic (originally suggested by Bird and Dewey, 1970), unless a rifting event, as yet undocumented, also occurred.

Eastern North American detrital zircon ages and age ranges cited in support of a Gondwanan affinity include (1) combinations of 570 Ma, 1,500–1,550 Ma, and 2,600–2,750 Ma zircons, and absence of 1,000–1,150 Ma zircons from the eastern New England Appalachians (Karabinos and Gromet, 1993); (2) combinations of 515–635 Ma, abundant 1,967–2,282 Ma, and ~2,700 Ma zircons for a Florida basement sandstone (Mueller et al., 1994); (3) the combination of ~550–700 Ma arc magmatism with ~1,000–1,300 Ma and 1,500–1,550 Ma zircons from the Avalon terrane in Nova Scotia (Keppie et al., 1998); (4) the presence of ~550–700 Ma, 2,000–2,200 Ma, and minor components of ~1,000, 1,200, and 1,800 Ma zircons in samples from the late Paleozoic Magdalen basin near the Avalon and Meguma terranes in the Canadian Appalachians (Murphy and Hamilton, 2000); and (5) the presence of Neoproterozoic and 1,100–1,800 Ma with increased contributions of 1,800–2,500 Ma and Archean ages over time for younger Carolina terrane samples (Samson et al., 2001). Based on the presence of 2,200–2,400 Ma and ~1,400 Ma detrital zircons in the Pine Mountain window of Alabama, Heatherington et al. (1997) and Steltenpohl et al. (2001, this volume) suggested that the Hollis Quartzite may have been derived from west Gondwana and that the mixture of Laurentian (or South American Rondonian province) and probable Gondwanan detrital zircons favors deposition of the Hollis Quartzite roughly coeval with separation of the Pine Mountain crustal block from Gondwana. With the exception of the Hollis Quartzite, each of these studies noted the presence of Late Proterozoic to Early Cambrian and Archean detrital zircon components with varying, but minor, Early and Middle Proterozoic detrital zircon components.

Laurentian Connections

A Laurentian connection for the entire metasedimentary package northwest of the Carolina terrane was proposed in Hatcher's (1978) depositional model, wherein the western Blue Ridge and eastern Blue Ridge sedimentary packages were related as equivalent facies within an ocean basin that developed between the Laurentian margin and a rifted fragment of continental basement. In this model, western Inner Piedmont paragneisses were deposited on the eastern margin of the rifted continental basement block. Detailed field work in the eastern Blue Ridge and western Inner Piedmont connected stratigraphic sequences across the Brevard fault zone that separates these divisions (e.g., Heyn, 1984; Hopson and Hatcher, 1988) and identified nonconformable or locally faulted basement-cover contacts around small massifs of the eastern Blue Ridge (Hatcher et al., this volume). These relationships and our new data suggest that eastern Blue Ridge–western Inner Piedmont paragneisses are correlative, and/or perhaps time-transgressive equivalents, to the western Blue Ridge cover sequences that are known to unconformably overlie Grenville basement. Recently published Nd and inherited zircon data demonstrate that Ordovician arc rocks of the Chopawamsic and Milton terranes (Coler et al., 2000) are isotopically more evolved than Gondwanan-affinity arcs (Nance and Murphy, 1994; Samson et al., 1995), and show remarkable similarities to recognized Laurentian arc terranes (e.g., Bronson Hill anticlinorium), Blue Ridge Grenvillian basement, and Blue Ridge–western Inner Piedmont paragneisses (Fig. 3).

Detrital zircons from Newfoundland Humber zone rift-facies, drift-facies, and foreland-basin samples are interpreted to represent material derived from the Superior craton, Early Proterozoic, and Grenvillian orogenic belts, and Neoproterozoic rift-related magmatic rocks (Cawood and Nemchin, 2001). Studies of detrital zircon age components in younger central and northern Appalachian Paleozoic foreland sedimentary sequences also favor Laurentian derivation (Gray and Zeitler, 1997; McLennan et al., 2001). Thus, it is likely that at least a portion of the older rift-and-drift Laurentian margin siliciclastic hinterland (relative to the Paleozoic foreland) source assemblage was originally derived from Laurentia.

DISCUSSION

Although whole-rock Nd isotopic data and detrital zircon ages can provide important information concerning the evolution of metasedimentary rocks, a surprisingly limited amount of these data exist for the southern Appalachians. Three crustal affinities are probable for Blue Ridge and Inner Piedmont metasedimentary samples: (1) Laurentian derivation, (2) west Gondwanan derivation, or (3) a combination of Laurentian and west Gondwanan derivation. Our data (Figs. 4 and 5) taken alone do not preclude any of the aforementioned scenarios, but our data differ from those of similar studies in the southern Appalachians (e.g., Heatherington et al., 1997; Miller et al., 2000; Steltenpohl et al., 2001, this volume) because of the presence of an Early Proterozoic component, albeit minor, for most southern Appalachian divisions. Based on the occurrence of the major age ranges of our data, the source(s) must include Grenvillian rocks and 1,250–1,400 Ma source components for all of the terranes sampled. Additionally, most divisions also contain varying amounts of 1,350–1,500 Ma zircon ages. Archean source(s) are required for our zircon suites in the central Blue Ridge, Dahlonega gold belt, and eastern Inner Piedmont. The Dahlonega gold belt also contains an appreciable detrital zircon component of ~1,600–2,100 Ma, which is not nearly as abundant in the other divisions (limited to single analyses in the western Blue Ridge and eastern Inner Piedmont).

Notably, two grains from the Dahlonega gold belt are 2,000–2,100 Ma, an age range not abundant in the Laurentian craton. Ordovician detrital zircons in the eastern Inner Piedmont samples indicate Late Silurian to Devonian deposition, likely between the proximal Laurentian margin and approaching peri-Gondwanan terrane(s).

Some researchers have contended that the entire package of rocks from the Valley and Ridge and the western Blue Ridge boundary to the southeastern boundary of the Inner Piedmont is Laurentian (e.g., Hatcher, 1978, 1987, 1989); others, however, have proposed that all rocks east of the Allatoona–Hayesville–Holland Mountain–Gossan Lead fault are exotic to North America (e.g., Rankin et al., 1989; Hibbard and Samson, 1995). Our data, as well as data from the Chopawamsic and Milton terranes (Coler et al., 2000), suggest that these terranes were either built on or interacted with Mesoproterozoic crust. Southern Appalachian basement rocks are mostly Grenvillian (Carrigan et al., 2003; Hatcher et al., this volume); studies in the Mars Hill terrane in the western Blue Ridge, however, have identified older whole-rock isotopic components (Monrad and Gulley, 1983; Sinha et al., 1996; Carrigan et al., 2003; Ownby et al., this volume) and pre-Grenvillian zircons with an abundant 1,200–1,300 Ma component and fewer 1,400–1,500 Ma, 1,600–1,900 Ma, and 2,700 Ma components (Fullagar and Gulley, 1999; Carrigan et al., 2003; Ownby et al., this volume). Consequently, Blue Ridge basement rocks or their eroded and/or subsurface equivalents are the best candidates for abundant Grenvillian detrital zircons and lesser amounts of Middle and Early Proterozoic detrital zircons. The combination of 1.3–1.5 Ga and Grenvillian detrital zircons is readily explained by a midcontinent granite-rhyolite terrane source with transport through or along the eroding Grenville orogen.

Our samples are largely dominated by zircons in the ~900–1,400 Ma range and roughly resemble detrital zircon data from Paleozoic sedimentary rocks in the northern Appalachian foreland (Middle Ordovician Austin Glen Member of the Normanskill Formation and Lower Silurian Shawangunk Formation; Gray and Zeitler, 1997; McLennan et al., 2001) and Newfoundland Humber Zone basal sedimentary units (Bradore and Summerside Formations; Cawood and Nemchin, 2001). They contrast markedly with northern Appalachian and Florida basement samples that are largely devoid of Grenvillian detrital zircons (Karabinos and Gromet, 1993; Mueller et al., 1994; Murphy and Hamilton, 2000; Samson et al., 2001). Except for eastern Inner Piedmont zircons, our data essentially lack the Neoproterozoic–Early Cambrian component of Gondwanan terranes and show a reasonable overlap with age distributions constructed for the southern Grenville by Cawood and Nemchin (2001 and references therein). Post-Grenvillian detrital zircon ages could represent sediment input from one or more of the following: pan-African crustal fragments (e.g., the Carolina terrane), Amazonian Brasiliano detritus (Keppie et al., 1998), late Neoproterozoic rift-related igneous rocks (e.g., Crossnore plutons or Catoctin Formation equivalents; Cawood and Nemchin, 2001), or Ordovician magmatic rocks (eastern Inner Piedmont only). Detrital zircon data for the Dahlonega gold belt and the single central Blue Ridge Coleman River Formation sample are distinct due to an Archean component in each and an early Middle Proterozoic age population in the Dahlonega gold belt. Samples from the Dahlonega gold belt represent the best candidates for a mixed Laurentian and Gondwanan affinity; however, this is difficult to explain, because these terranes are structurally beneath the eastern Blue Ridge and western Inner Piedmont, which are most likely derived from Laurentia. One possibility is that sediments of the Dahlonega gold belt and associated Ordovician arcs are younger than surrounding sediments of the Chattahoochee and Hayesville–Soque River thrust sheets and reflect a different sediment-transport direction and/or sources not exposed during initial rifting.

Exotic Pine Mountain block cover sequences place Grenville basement of the block proximal to a west Gondwanan source or sources (Steltenpohl et al., this volume); however, the present position of the block and its unique provenance relative to the now adjacent Inner Piedmont and nearby Blue Ridge may be variably interpreted. Surface geologic data from carbonate horses in the Brevard fault zone (Hatcher et al., 1973), matching Valley and Ridge reflector characteristics with those beneath the Brevard fault zone (Clark et al., 1978), and regional seismic reflection data (Cook et al., 1980; Costain et al., 1989) from the Blue Ridge and Inner Piedmont of Georgia and Carolinas place the crystalline thrust sheets of the eastern Blue Ridge and Inner Piedmont above Valley and Ridge carbonate and clastic rocks. Seismic reflection data from the Pine Mountain block and vicinity (Nelson et al., 1987) provide evidence of Valley and Ridge–type rocks on basement at the northwestern edge of the block. Early accretion of an exotic Pine Mountain block to the Laurentian margin with its Grenville basement and Paleozoic clastic-carbonate cover, followed by development of high- and low-temperature Alleghanian shear zones (Steltenpohl et al., 1992; Student and Sinha, 1992; Steltenpohl and Kunk, 1993; Hooper et al., 1997), and final detachment along the master Appalachian décollement beneath the window is compatible with available data (Hooper and Hatcher, 1988; McBride et al., 2001) and accounts for the present position of the block in the southern Appalachians.

SUMMARY

Laurentian crustal affinity is favored here for paragneisses in the southern Appalachian Blue Ridge and western Inner Piedmont. This view is based on (1) the presence and availability of eastern North America cratonic and basement material with the same ages found in southern Appalachian Blue Ridge and western Inner Piedmont detrital zircons, (2) overlap of Nd isotopic values for southern Appalachian metasedimentary rocks and Grenvillian basement, and (3) a paucity of distinctly Gondwanan detrital zircons. Laurentian provenance requires that (1) marginal basins were isolated from west Gondwanan source(s)

from the time of Rodinian rifting at least until the Middle Ordovician, (2) sources include early Middle Proterozoic rocks from the Mid-Continent granite-rhyolite province or the Mars Hill terrane, (3) the Pine Mountain block is either entirely exotic (inclusive of its 1.1 Ga basement) or represents a far-traveled fragment of Laurentia, and (4) paragneisses of the eastern Blue Ridge and western Inner Piedmont are time-transgressive or rift-facies equivalents of western Blue Ridge paragneisses. Gondwanan affinity of some zircons in a few terranes (e.g., Dahlonega gold belt and Cowrock) requires that these sediments were deposited proximal to a Grenville belt in western Gondwana and were sutured to the Laurentian margin during the Taconic and/or Acadian orogenic events. A mixed provenance is plausible for the Dahlonega gold belt but this creates significant tectonic and depositional issues because of its location between and beneath terranes that have connections to Laurentia. Eastern Inner Piedmont samples contain detrital zircon components similar to those in Blue Ridge and western Inner Piedmont samples, but also contain abundant Ordovician and lesser Silurian, Early Devonian, Gondwanan components, thus favoring post-Early Devonian deposition and mixed Laurentian and Gondwanan provenance.

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