U-Pb ages from the Dadeville Complex, southernmost Appalachians, eastern Alabama: an accreted Taconic arc

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ABSTRACT

The Inner Piedmont comprises a suspect terrane of high-grade metasedimentary, metavolcanic, and metaplutonic rocks that extends throughout the southern Appalachians. In eastern Alabama, the precise age and tectonic affinity of these rocks is not well defined. Some units previously correlated to the Inner Piedmont in Alabama are in fact a part of the eastern Blue Ridge terrane (i.e., the Opelika Complex) so now only the Dadeville Complex is considered to have a true Inner Piedmont affinity. The Dadeville Complex is a package of interlayered amphibolite and felsic schist (Waresville Formation), layered to massive amphibolite and tonalitic gneiss (Ropes Creek Amphibolite), tonalitic gneiss (Waverly Gneiss), two different felsic intrusives suites (the Camp Hill Gneiss and the Rock Mills Granite Gneiss), and a migmatitic aluminous schist (Agricola Schist). The only previously reported age for Dadeville Complex rocks is a Rb-Sr whole-rock isochron age of 462 ± 4 Ma for the Franklin Gneiss in western Georgia (i.e., the Rock Mills Granite Gneiss in Alabama).

Samples were collected from the type localities of six constituent units comprising the Dadeville Complex and their zircons were extracted for LA-SF-ICPMS dating. Magmatic zircons yielded $^{206}Pb/^{238}U$ ages of 493.4 ± 6.0 Ma for the Waresville Formation, 476.6 ± 6.8 Ma for the Ropes Creek Amphibolite, 477.1 ± 4.8 Ma for the Waverly Gneiss, and 499.8 ± 6.9 Ma for the Camp Hill Gneiss. Although zircons from the Rock Mills Granite Gneiss were too strongly altered for analysis, the previously reported Rb-Sr date is compatible with our new geochronologic results documenting Early to Middle Ordovician development of the Dadeville Complex. Detrital zircons from the Agricola Schist yielded $^{206}Pb/^{238}U$ dates spanning from ~2.7 Ga to ~400 Ma, with peaks at ~883, ~755, and ~656; a prominent age population at ~480 Ma has Th/U values (<0.1) and is interpreted as metamorphic overgrowth. The detrital dates do not coincide with typical zircon producing events found along the southeastern (present-day) Laurentian margin; Grenville zircons are conspicuously sparse (5.3%) and only reflect the very latest stages of orogenesis. Results indicate that the Dadeville Complex is an exotic island arc emplaced onto the eastern Laurentian margin during the Taconic.

Keywords: Dadeville Complex, Inner Piedmont, southern Appalachians, eastern Alabama

GEOLOGIC SETTING

The Dadeville Complex comprises a suspect terrane of high-grade metasedimentary, metavolcanic, and metaplutonic rocks that extends throughout the Inner Piedmont of eastern Alabama. These rocks contain peak upper amphibolite-facies metamorphic mineral assemblages that were locally retrograded at upper greenschist-facies conditions during ductile shearing associated with Alleghanian reactivation of the Brevard shear zone (Steltenpohl and Moore, 1988; Steltenpohl and Kunk, 1993; Steltenpohl, 2005). Geochemical analyses of amphibolites and ultramafic by Neilson and Stow (1986), Hall (1991), and Sterling (2006) indicates that these rocks evolved in an arc setting distal to the Neoproterozoic Laurentian margin, and later geochemical analyses by Neilson et al. (1996) indicates that the felsic metaplutonics evolved in a volcanic island-arc. Despite these interpretations however, the true tectonic affinity and accretionary history of the Dadeville Complex remains unknown (Steltenpohl and Moore, 1988; Steltenpohl and Kunk; 1993).

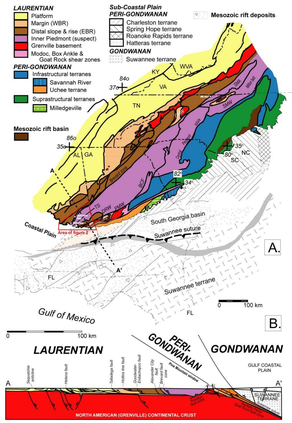


Figure 1: (A) Tectonic map illustrating Alabama's position within the southern Appalachians with cross section line A-A' (from Steltenpohl et al., 2007, 2013; as modified from Hatcher, 2004, Horton et al., 1989; Hibbard et al., 2002; Steltenpohl, 2005). The red polygon illustrates the area of Fig. 2. (B) Simplified cross section A-A' (modified from W.A. Thomas and coworkers as depicted in Thomas et al. [1989], Hatcher et al. [1990], and Steltenpohl [2005]). Map abbreviations: BCF–Brindle Creek fault; CR–Cartersville reentrant; CST–Cat Square terrane; DRW–Dog River window; EBR–eastern Blue Ridge; GMW–Grandfather Mountain Window; HLF–Hollins Line fault; PMW–Pine Mountain window; SMW–Sauratown Mountain Window; SRA–Smith River allochthon; TS–Tallassee synform; WBR–western Blue Ridge. Cross Section: A–away; T–toward; no vertical exaggeration.

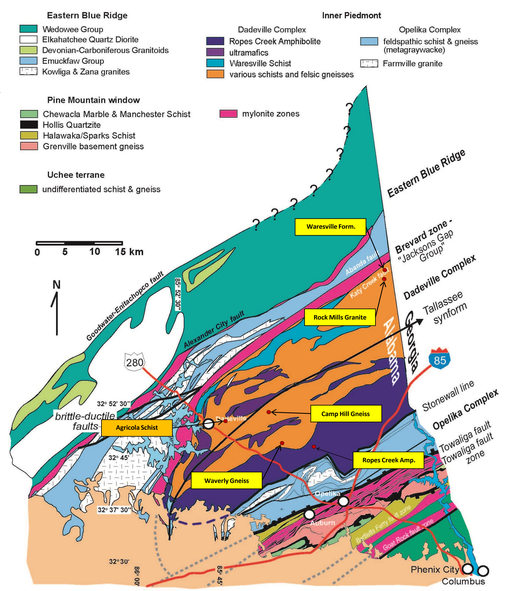
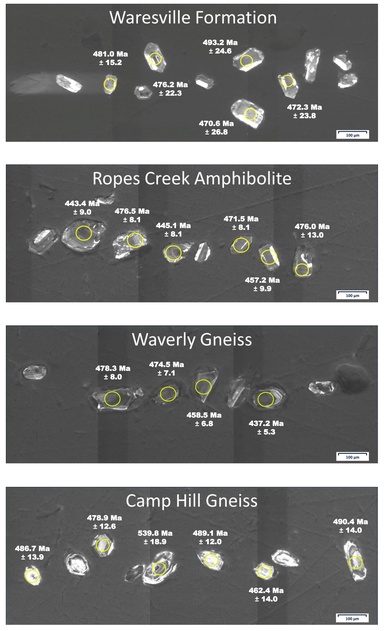


Figure 2: Geologic map of the Alabama Piedmont (from Osborne et al., 1988, Steltenpohl, 2005, and Steltenpohl et al., 2013) showing the location of Dadeville Complex rocks targeted for U-Pb dating; the yellow boxes indicate targets for magmatic zircons and the orange box indicates the targets for detrital zircons. Dashed gray lines are geophysical lineaments from Horton et al. (1989). Dashed blue line represents the base of the Dadeville Complex from White (2007).

METHODS

Samples for $^{206}Pb/^{238}U$ age dating were collected from their respective type localities within the Dadeville Complex. Zircons were extracted using standard heavy mineral separation techniques, and imaged using scanning electron microscope (SEM) cathodoluminescence. The age dating was performed using the facilities in the LA-SF-ICPMS Lab at California State University, Northridge following the methodology of Fryer et al. (1993). The 100 µm diameter laser ablated a ~40 µm pit. Measured $^{206}Pb/^{238}U$ ratios were normalized to the values of zircon standard Plešovice (Sláma et al., 2008). Data were reduced using SQUID-2 (Ludwig, 2009) and plotted using Isoplot v. 3.75 (Ludwig, 2012). U-Pb age data that were more than 10% discordant were excluded from the detrital plots.



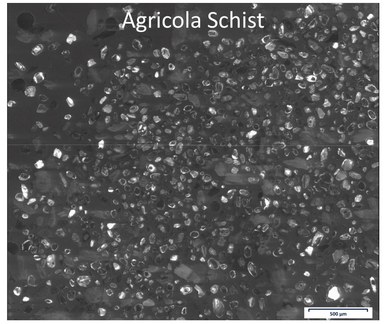


Figure 3: Scanning electron microscope (SEM) cathodoluminescent (CL) images of magmatic (left) and detrital (right) zircons targeted for $^{206}Pb/^{238}U$ age dating.

MAGMATIC ANALYSIS

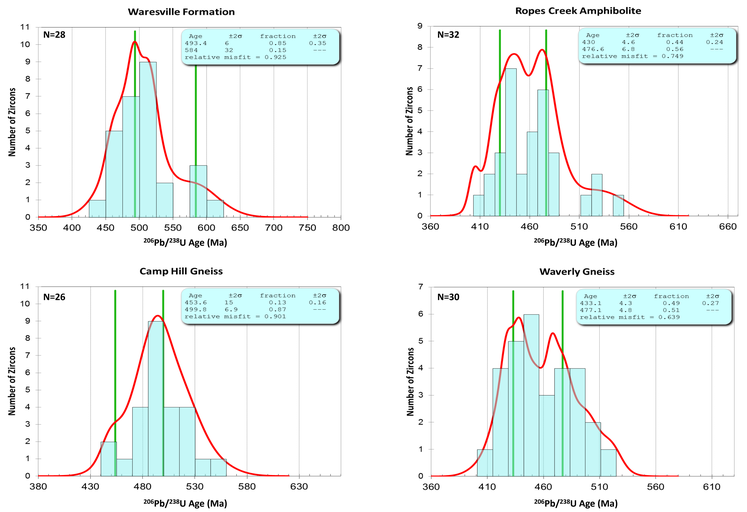


Figure 4: Relative probability plots with histograms of $^{206}Pb/^{238}U$ age data collected from magmatic zircons extracted from the Waresville Formation (top left), the Ropes Creek Amphibolite (top right), the Waverly Gneiss (bottom right), and the Camp Hill Gneiss (bottom left). We interpret the older ages obtained as being reflective of the actual age of igneous crystallization.

DETRITAL ANALYSIS

Detrital zircons from the Agricola Schist yielded $^{206}Pb/^{238}U$ dates spanning from ~2.7 Ga to ~400 Ma, with peaks at ~883 Ma, ~755 Ma, ~656 Ma, and ~480 Ma. These zircon populations, with the exception of ~the 480 Ma one, are not typical of Laurentian sources. The discrepancy in age populations and the absence of a prominent Grenville signature in the Agricola Schist indicates the Dadeville Complex is an exotic terrane that developed distal to a Laurentian source. A prominent detrital zircon population (8.5%) at ~480 Ma has Th/U values (<0.1) and is interpreted as being evidence for Taconian metamorphism.

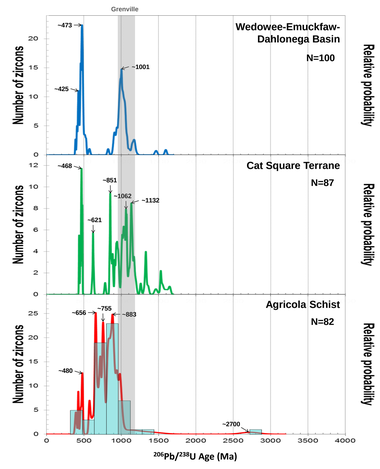


Figure 5: Relative probability plots comparing the detrital zircon populations of the Agricola Schist (red), Cat Square Terrane (Merschat et al., 2010) (green), and Wedowee-Emuckfaw-Dahlonega Basin (Tull et al., 2014) (blue). Grenville-aged zircons are conspicuously sparse (5.3%) in the Agricola Schist, and reflect only the very latest stages of that orogeny.

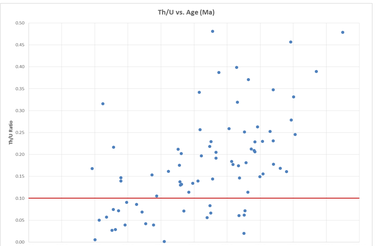


Figure 6: Plot of Th/U ratios measured in detrital zircons from the Agricola Schist. Th/U values (<0.1) are interpreted as being evidence for metamorphic overgrowth (Hartman et al., 2000).

CONCLUSIONS

The conclusions for this investigation of the Dadeville Complex are four-fold:

1. The magmatic ages obtained during our analyses are compatible with the previously reported age for the Franklin Gneiss and confirm that the Dadeville Complex contains volcanic and plutonic rocks of an Early to Middle Ordovician age.
2. Detrital age populations for the Agricola Schist do not coincide with the typical zircon producing events found along the present-day south-eastern Laurentian margin. The Agricola differs from both the Wedowee-Emuckfaw-Dahlonega and Cat Square basin rocks in that the latter two display prominent Grenville populations.
3. A prominent detrital zircon population (8.5%) at ~480 Ma have Th/U values less than 0.1 and is the first documentation for Taconian metamorphism in the southernmost Appalachians.
4. These results, in conjunction with the geochemical analyses of Neilson et al. (1996) and others, indicates that the Dadeville Complex is an Ordovician-aged exotic island-arc accreted onto eastern Laurentia during the Taconic orogeny.

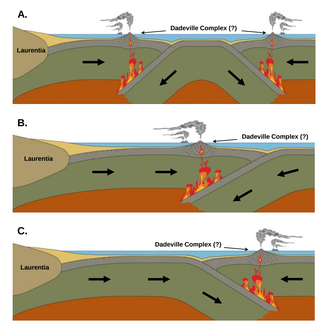


Figure 7: Three models depicting the origin of the Dadeville Complex island-arc during the Early to Middle Ordovician. Models show the island-arc forming as a result of: **A.** Dual subduction (after McClellan et al., 2007); **B.** Westward subduction (after Tull et al., 2014); and, **C.** Eastward subduction.

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