

## **MISSISSIPPIAN (CA. 326-323 MA) U-PB CRYSTALLIZATION AGES FOR TWO GRANITOIDS IN SPARTANBURG AND UNION COUNTIES, SOUTH CAROLINA**

ALLEN J. DENNIS, Department of Biology and Geology,  
University of South Carolina-Aiken, Aiken SC 29801-6309  
JAMES E. WRIGHT, Department of Geology and Geophysics,  
Rice University, Houston TX 77005

### **Introduction**

Two granitoids were identified for U-Pb zircon dating in the course of detailed mapping in the Glenn Springs and Jonesville 7.5' quadrangles. This area is of interest because it contains the boundary between the Carolina terrane and Inner Piedmont. This boundary is hereafter referred to as the central Piedmont suture of Hatcher and Zietz, but is known in this area also as the Cross Anchor fault of Willis (1984). In the map area underlain by the Carolina terrane, mafic to intermediate volcanic and plutonic rocks metamorphosed to greenschist to lowermost amphibolite facies predominate (Dennis and Shervais, 1991, 1995). A companion investigation has outlined the age relations of these rocks, and concludes that magmatism was coeval with metamorphic fabric development in Late Precambrian through Early Cambrian time (Dennis and Wright, 1993, 1996). The Inner Piedmont is characterized in this area by a variety of ortho- and paragneisses that have generally low dips and are slabby in appearance. Several middle Paleozoic plutons also outcrop in this general area including the Pacolet granite ( $383 \pm 7$  Ma, Rb-Sr whole-rock, Mittwede and Fullagar, 1987; Mittwede, 1989) and the undated Buffalo gabbro (Medlin and others, 1972). Structural analysis and an interpretation of the sequence of events that affected this area of the Piedmont are presented in Dennis (1995). Data in this contribution were collected from rocks of the Bald Rock granite and an unnamed granite that appears to cut the central Piedmont suture.

### **Description of rock bodies**

#### **Bald Rock granite**

The Bald Rock pluton is an elliptical granite body that covers all or parts of seven 7.5' quads and is centered on the Kelton 7.5' quad north of Union, South Carolina. On its western margin in the Jonesville quad, the pluton intrudes mafic metavolcanic rock, metadiorite and diorite gneiss. Foliation attitudes in Carolina terrane rocks adjacent to the pluton are subparallel to that contact. Mappable blocks of country rock (metagabbro and sillimanite schist of the Battleground Formation) are present within the pluton. To the east, in York and Chester Counties, intermediate-ultramafic volcanic and plutonic rocks also comprise the country rock, but the metamorphic grade is higher and the structural story appears more complex (e.g., Neal Shoals on the 1995 Carolina Geological Society field trip, Dennis and others, 1995).

The Bald Rock pluton is most easily identified as a coarse-grained megacrystic granite with potassium feldspar phenocrysts 5-7 cm in length. These megacrysts are typically highly aligned and concordant with elliptical xenoliths and/or mafic enclaves. Speer and others (1986) identify five facies within the Bald Rock pluton, and present a fabric map that shows the regional pattern defined by megacrysts and flattened mafic enclaves. McSween and others (1991) correctly anticipated a Carboniferous age for the Bald Rock pluton, based in part on a comparison of its mafic mineral chemistry with that of other Southern Appalachian Carboniferous plutons (Speer and others, 1986).

Weathered flat rock pavements are quite common in the area underlain by the pluton, but it is generally difficult to find large outcroppings of fresh rock. The sample dated here came from an inactive quarry located on the Hyder Farm in the Kelton quad identified in Wagener (his U2, 1977). This outcrop will be visited by the 1995 Carolina Geological Society Field Trip (Dennis and others, 1995). The latitude and longitude of the sample site are  $34^{\circ}47'15''N$  and  $81^{\circ}33'18''W$ .

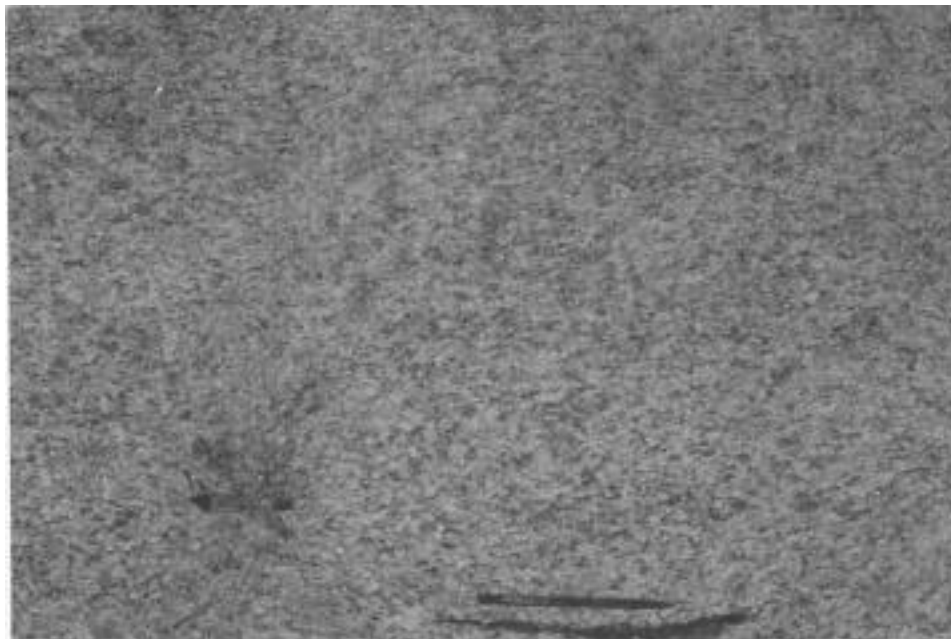


Fig. 1. Pavement of unnamed granitoid (sample 1823) intruding the central Piedmont suture along Dutchman Creek, Glenn Springs 7.5' quadrangle, South Carolina. Pencil points north. Note schlieren and weak compositional layering oriented approximately N-S.

***Unnamed granite on Dutchman Creek, Glenn Springs quad.***

This small (2 km diameter) foliated granitic body was mapped by Dennis (1989), and interpreted to cross cut the central Piedmont suture. This granitoid is mapped in contact with Inner Piedmont ortho- and paragneisses, including augen gneiss, sillimanite schist, and amphibolite to the southwest, and Carolina terrane to the east and north. To the east the granite is in contact with felsic metavolcanic rocks and to the north with mafic metavolcanic rocks. Dennis (1989) mapped a small ultramafic body near the southeastern margin of the pluton.

The rock contains a fabric that is defined by alignment of microcline phenocrysts and crude compositional layering defined by feldspars and quartz and is parallel to biotite-rich schlieren in the rock (Figure 1). The strike of this fabric is oriented within 30° of north where it is observed, and is approximately subparallel to the trace of the central Piedmont suture in this area. Dips are consistently to the east and range from 30° to vertical. Locally a nearly strike-parallel lineation is apparent and plunges south. In the metavolcanic rocks a parallel lineation is observed, and in that rock is interpreted to be

parallel to the regional fold axis. There is no consistent variation or difference between the orientation of the slaty cleavage in the metavolcanic rocks and the weak fabric in the granitoid.

The outcrop (1823) where the sample was collected is located in the southeastern corner of the Glenn Springs quad at the intersection of Dutchman Creek and Friendship Church Road (S-42-112), 0.4 mile south of the intersection of S-42-112 with SC 56. The latitude and longitude of the sample site are 34°46'24"N and 81°51'03"W.

**U-Pb Geochronology**

***Analytical Procedures***

Analytical procedures were the same as those described by Wright and Fahan (1988) and Dilles and Wright (1988). Isotopic data were determined on a multicollector Finnigan Mat 262 mass spectrometer at Rice University. Total Pb blanks at Rice have ranged over the years from as little as 10 pg to as much as 100 pg. Concordia intercepts were calculated using the program of Ludwig (1984). Further details of analytical procedures and error analysis are contained in Table 1.

Table 1. URANIUM-LEAD ISOTOPIIC DATA

Sample #	Total U ppm	206Pb* ppm	Measured Ratios**					Atomic Ratios				Apparent Ages (Ma)§		
			206Pb 204Pb	207Pb 206Pb	208Pb 206Pb	206Pb* 238U	207Pb* 235U	207Pb* 206Pb*	206Pb 238U	207Pb 235U	206Pb 207Pb	207Pb 235U	207Pb 206Pb	
AD-1823	100-200	28.42	5076	0.05482	0.24089	0.04760	0.34741	0.05294	299.7	302.8	326+/-2			
AD-1823	200-325	1031	9346	0.05411	0.18170	0.04863	0.35488	0.05293	306.1	308.4	326+/-2			
AD-1823	-325	1078	8474	0.05426	0.18986	0.04817	0.35148	0.05292	303.3	305.8	325+/-2			
Hyder	100-200	1107	7042	0.05456	0.16387	0.04982	0.36301	0.05284	313.4	314.5	322+/-2			
Hyder	200-325	1035	2825	0.05764	0.19776	0.05063	0.36902	0.05286	318.4	318.9	323+/-2			
Hyder	-325	1034	3448	0.05669	0.20800	0.05064	0.36904	0.05285	318.4	318.9	322+/-2			

# +200, 100-200, refer to size fractions in mesh

\* Denotes radiogenic Pb, corrected for common Pb using the isotopic composition of 206Pb/204Pb=18.6 and 207Pb/204Pb=15.6. Sample dissolution and ion exchange chemistry modified from Krough (1973).

\*\* Isotopic compositions corrected for mass fraction (0.11% per A.M.U.)

§ Ages calculated using the following constants: decay constant for 235U and 238U = 9.8485E-10 and 1.55125E-10yr-1 respectively; 238U/235U = 137.88.

Error analysis for individual zircon fractions follows Mattinson (1987). Concordia intercepts and errors calculated using program of Ludwig (1984).

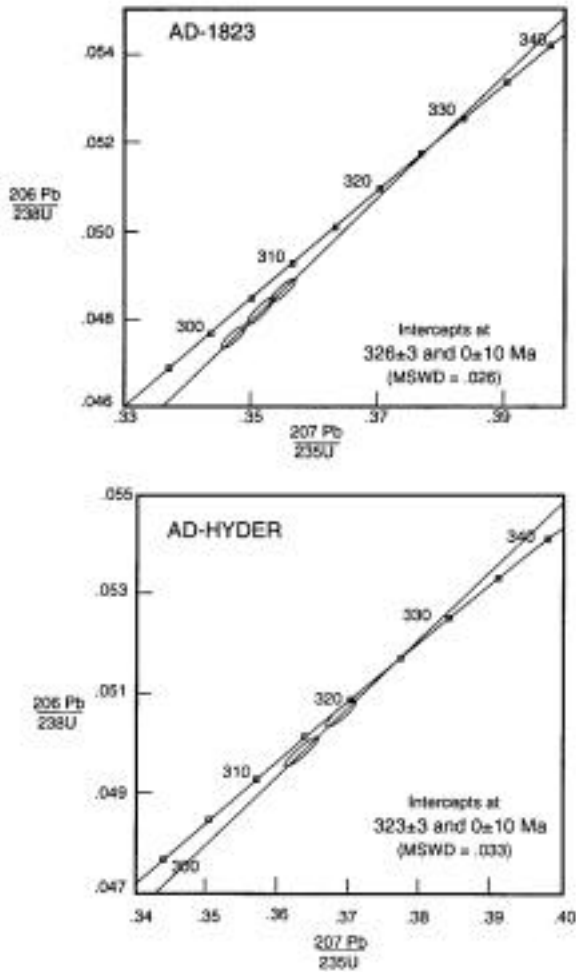


Fig. 2. Concordia diagrams for unnamed granitoid (AD-1823) and Bald Rock granite (AD-HYDER)

### Analytical results.

As is evident from the isotopic data all analyzed zircon fractions from each sample have lost moderate amounts of radiogenic lead, but  $^{207}\text{Pb}^*/^{206}\text{Pb}^*$  dates agree within analytical error for the individual samples (Table 1). We interpret these results to indicate recent loss of radiogenic lead. In addition, there is no evidence of an older, premagmatic zircon component. On the concordia diagram (Figure 2) sample AD-1823 (unnamed granite) gives an upper concordia intercept age of  $326 \pm 3$  Ma and sample Hyder (Bald Rock granite) gives an upper concordia intercept age of  $323 \pm 3$  Ma. The chords for each sample were force-fit through a lower concordia intercept of  $0 \pm 10$  Ma which is essentially averaging the  $^{207}\text{Pb}^*/^{206}\text{Pb}^*$

dates while taking into consideration the error associated with each data point on the concordia plot. This treatment is justified, in our opinion, due to the agreement of all  $^{207}\text{Pb}^*/^{206}\text{Pb}^*$  dates for each respective sample, and necessary due to the lack of spread in  $^{206}\text{Pb}^*/^{238}\text{U}$  for each respective sample.

### Interpretation

Results presented here confirm the inferences drawn by McSween and others (1991) that the Bald Rock is an Alleghanian granite and that the Bald Rock pluton belongs in the western group of Alleghanian granites (York-High Shoals- Churchland; e.g., Horton and others, 1987). A Late Paleozoic tectonothermal event has been identified in the central Piedmont on the basis of  $^{40}\text{Ar}/^{39}\text{Ar}$  mineral ages (Dallmeyer and others, 1986, Horton and others, 1987). The relationship between this event and plutonism in the central Piedmont is most clearly displayed in the vicinity of the High Shoals granite (Horton and others, 1987); elsewhere this relation is less clear. Intrusion of the Bald Rock and other Alleghanian plutons may be responsible for the "annealed" country rock fabric described by Dennis and Shervais (1991). It is suggested that the location of the Bald Rock may have been controlled by existing faults, especially given the contrast in grade and/or structural style between the country rock on the east and west sides of the pluton.

The unnamed granite is interpreted to cut the central Piedmont suture. Thus, the central Piedmont suture in this area is a pre-Alleghanian feature. The lineation, a magmatic to submagmatic fabric, and possibly some penetrative, solid-state deformation are here interpreted to be related to northwest-vergent Alleghanian folding and what Dennis (1995) interprets to be no more than minor ductile motion along the 50 km N-S trending segment of the central Piedmont suture between Spartanburg and Clinton. The central Piedmont suture is interpreted to have controlled the location of the intrusion. Alternatively, the granitoid may be related to augen gneisses of the Inner Piedmont recognized 2 km southwest of this outcrop on Trail Branch. However, the existence of

Carboniferous orthogneisses in the eastern part of the Inner Piedmont has not been documented.

Finally we note the lack of a xenocrystic zircon component or evidence of inheritance in these isotopic data. The origin of the southern Appalachian Alleghanian granites is a popular topic for speculation (e.g., Sacks and Secor, 1990; Speer and others, 1994). The data from these plutons does not indicate an origin in crustal anatexis or remobilization of Carolina terrane basement.

### Conclusions

We have documented two Carboniferous plutons in the western Carolina terrane of northwestern South Carolina. Three size fractions of zircon from the Bald Rock pluton yield an upper intercept of  $323 \pm 3$  Ma on a concordia diagram. Three size fractions of zircon from an unnamed granitoid that intrudes the central Piedmont suture in the Glenn Springs quadrangle yield an upper intercept at  $326 \pm 3$  Ma. Thus, in the Carolina terrane adjacent to the central Piedmont suture between Spartanburg and Union, three episodes of plutonism are identified. In the Late Precambrian-Early Cambrian (Mean Crossroads complex) ultramafic-intermediate composition intrusive rocks record the rifting of the Carolina arc at which time deep-seated faulting allowed highly magnesian magmas to ascend with little fractionation. In the Devonian the Pacolet granite and Buffalo gabbro intruded as parts of a linear post-metamorphic array of gabbros and granitoids that is largely restricted to the area just south and east of the central Piedmont suture. In the Carboniferous the Bald Rock and unnamed granite are part of the well known group of granitic plutons that cover the entire age range of the Alleghanian orogeny mapped in the Carolina terrane and are related to that collision.

### Acknowledgements

Support for U-Pb geochronologic studies was provided by the South Carolina Universities Research and Education Foundation (Task 14) and NSF EAR 91-17915. Thanks to John Shervais for his helpful review.

### References

- Dallmeyer, R.D., Wright, J.E., Secor, D.T. and Snoke, A.W., 1986, Character of the Alleghanian orogeny in the southern Appalachians. Part II. Geochronological constraints on the tectonothermal evolution of the eastern Piedmont in South Carolina : Geological Society of America Bulletin, v. 97, p. 1329-1344.
- Dennis, A.J., 1989, Tectonogenesis of an accreted terrane: The Carolina arc in the Paleozoic: [Ph.D. thesis]: Columbia, University of South Carolina, 139 p.
- Dennis, A.J. and Shervais, J.W., 1991, Evidence for arc rifting along the Carolina terrane boundary in northwestern South Carolina: *Geology*, v. 19, p. 226-229.
- Dennis, A.J. and Shervais, J.W., 1995, The Carolina terrane in northwestern South Carolina: Insights into the development of an evolving island arc, in Nance, R.D. and Thompson, M.D., eds., *Avalonian and related peri-Gondwanan terranes of the Circum-North Atlantic*: Geological Society of America Special Paper 304, in press.
- Dennis, A.J., 1995, The Carolina terrane in northwestern South Carolina: Relative timing of events and recent tectonic models, in Hibbard, J.P., van Staal, C.R., and Cawood, P.A., eds., *New Perspectives in the Appalachian-Caledonian Orogen*: Geological Association of Canada Special Paper 41, in press.
- Dennis, A.J. and Wright, J.E., 1993, New Late Precambrian-Cambrian U-Pb zircon ages for zoned intrusives in the western Carolina terrane, Spartanburg and Union Counties, South Carolina [abstract]: *Geological Society of America Abstracts with Programs*, v. 25, p. 12.
- Dennis, A.J. and Wright, J.E., 1996, The Carolina terrane in northwestern South Carolina, USA: Age of deformation and metamorphism in an exotic arc: *Tectonics*, accepted pending revision.
- Dilles, J.H. and Wright, J.E., 1988, The chronology of early Mesozoic arc magmatism in the Yerington district of western Nevada and its regional implications: *Geological Society of America Bulletin*, v. 100, p.644-652.
- Hatcher, R.D., Jr. and Zietz, I., 1980, Tectonic implications of regional aeromagnetic and gravity data from the southern Appalachians, in Wones, D.R., ed., *The Caledonides in the U.S.A.*: Virginia Polytechnic Institute, Department of Geological Sciences Special Publication 2, p. 235-244.

- Horton, J.W., Jr., Sutter, J.F., Stern, T.W. and Milton, D.J., 1987, Alleghanian deformation, metamorphism and granite emplacement in the central Piedmont of the southern Appalachians: *American Journal of Science*, v. 287, p. 635-660.
- Krogh, T.E., 1973, A low contamination method for hydrothermal decomposition of zircon and extraction of U and Pb for isotopic age determinations: *Geochimica and Cosmochimica Acta*, v. 37, p. 485-494.
- Ludwig, K.R., 1984, Plotting and regression programs for isotope geochemists, for use with HP-86/87 microcomputers: U. S. Geological Survey Open File Report 83-849, 102 p.
- Mattinson, J.M., 1987, U-Pb ages of zircon: A basic examination of error propagation: *Chemical Geology (Isotope Geology Section)*, v. 66, p.151-162.
- McSween, H.Y., Speer, J.A. and Fullagar, P.D., 1991, Plutonic rocks, in J.W. Horton, Jr. and V.A. Zullo ed., *The Geology of the Carolinas: Knoxville, University of Tennessee Press*, p. 109-126.
- Medlin, J.H., Thornton, C.P. and Gold, D.P., 1972, Petrology of the mafic igneous complexes in the southeastern U.S. Piedmont: II. The Buffalo mafic igneous complex, Union County, South Carolina: *Southeastern Geology*, v. 14., p. 73-106.
- Mittwede, S.K., 1989, Geologic maps of the Pacolet and Pacolet Mills 7.5' quadrangles, South Carolina: OFR-64: Columbia, SC, South Carolina Geological Survey.
- Mittwede, S.K. and Fullagar, P.D., 1987, Petrology and geochemistry of the Pacolet monzogranite in northwestern South Carolina: Petrogenetic implications [abstract]: *Geological Society of America Abstracts with Programs*, v. 18, p. 118.
- Sacks, P.E. and Secor, D.T., Jr., 1990, Delamination in collisional orogens: *Geology*, v. 18, p. 999-1002.
- Speer, J. A., Brauer, S.V.G., and McSween, H.Y., Jr., 1986, The Bald Rock granitic pluton, South Carolina: Petrography and internal fabric: *South Carolina Geology*, v. 30, 1-17.
- Speer, J.A. , McSween, H.Y. and Gates, A.E., 1994, Generation, segregation, ascent and emplacement of Alleghanian plutons in the southern Appalachians: *Journal of Geology*, v. 102, p. 249-267.
- Wagener, H.D., 1977, The granitic stone resources of South Carolina: *Mineral Resources Series 5: Columbia, South Carolina Geological Survey*, 65 p.
- Willis, J. , 1984, *Geology of the Cross anchor area: The boundary between the Carolina terrane and the Inner Piedmont in northwestern South Carolina [M.S. thesis]: Columbia, University of South Carolina*, p. 61.
- Wright, J.E. and Fahan, M.R., 1988, An expanded view of Jurassic orogenesis in the western United States Cordillera: Middle Jurassic (pre-Nevadan) regional metamorphism and thrust faulting within an active arc environment: *Geological Society of America Bulletin*, v. 100, p. 859-876.