Siluro-Devonian assembly of the internal, high-grade core of the central Appalachian Piedmont

Howell Bosbyshell[1], hbosbyshell@wcupa.edu; Gale Blackmer[2], LeeAnn Srogi[1], William S. Schenck[3]

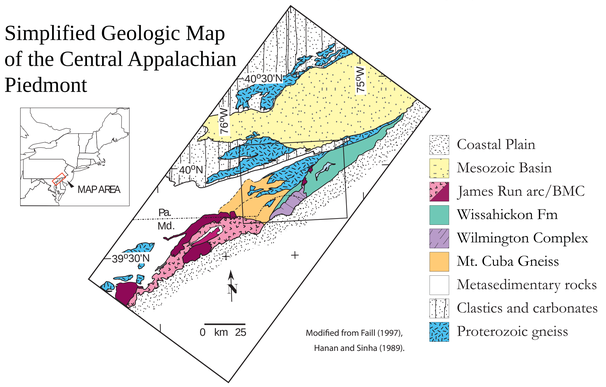
[1]West Chester University, [2]Pennsylvania Geological Survey, [3]Delaware Geological Survey

ABSTRACT

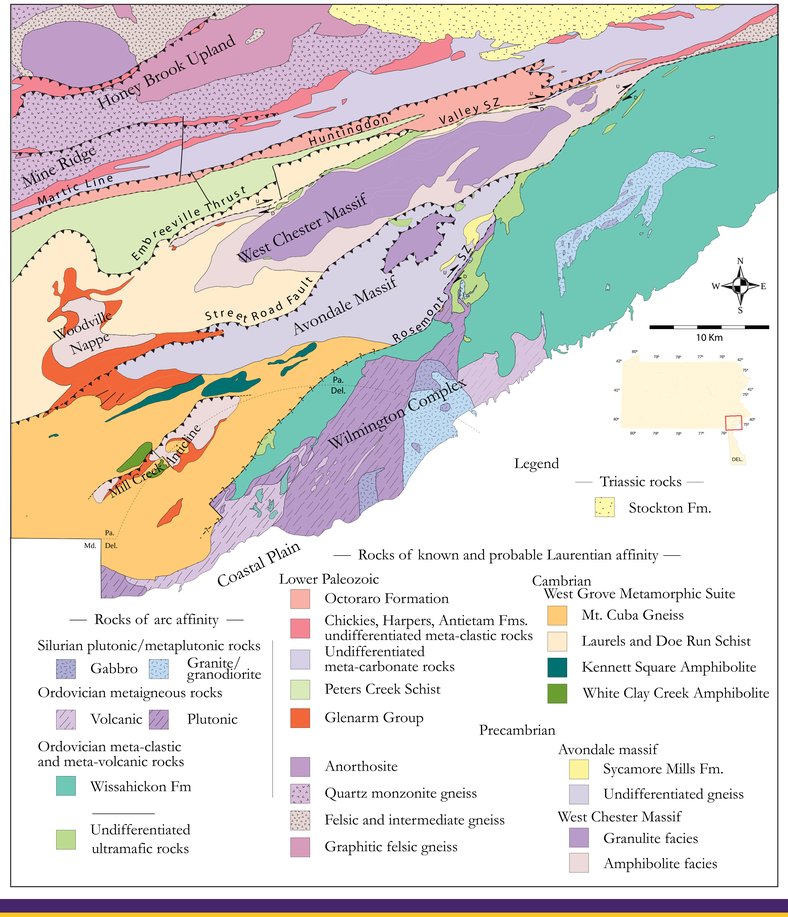
Amphibolite facies metamorphic rock of the West Grove Metamorphic Suite in the central Appalachian Piedmont of SE Pennsylvania and northern Delaware occurs in a stack of basement gneiss-cored nappes or thrust sheets bounded to the north by the Pleasant Grove-Huntingdon Valley shear zone (PGHV) and to the southeast by the Rosemont shear zone (RMZ); both are steeply dipping transcurrent shear zones. The granulite facies Wilmington Complex (WC) and amphibolite facies Wissahickon Fm. (WF) occupy the block east of the RMZ. From NW to SE and structurally lowest to highest, the nappes include the West Chester massif, the Woodville nappe, the Avondale massif and the Mill Creek Anticline. U-Th-total Pb monazite ages indicate that maximum temperatures in the Mill Creek were attained in the late Silurian prior to the highest temperatures in the structurally lower Avondale nappe. In turn, peak metamorphism in the structurally lowest unit, the Doe Run schist in the West Chester nappe, is even younger – maximum temperatures were not reached until 410 Ma (early Devonian). We interpret this sequence to represent successive stacking of thrust sheets from southeast to northwest with the warmer overriding sheets contributing to the thermal budget of lower sheets. This deformation and metamorphism is interpreted to be the result of the Silurian collision of Ganderia, in a sinistral transpressive tectonic regime (Hibbard et al., 2007; 2010). The geometry of thrust sheets relative to the steeply dipping PGHV shear zone is consistent with the sinistral restraining bend at the New York promontory in the Hibbard model.

The most recent ductile deformation in the PGHV is thought to reflect dextral motion; such motion could have transported the assembled nappes from a more northerly location. The middle Devonian age of monazite in the WF suggests that Barrovian metamorphism there is the result of crustal thickening during the Acadian orogeny, the accretion of Avalon in the northern Appalachians. Given the evidence for late Devonian and younger dextral transcurrent motion regionally on the PGHV and RMZ, and throughout the Appalachians, it is likely that the crustal block east of the RMZ which contains the Wissahickon Fm. and Wilmington Complex was originally located some distance to the north.

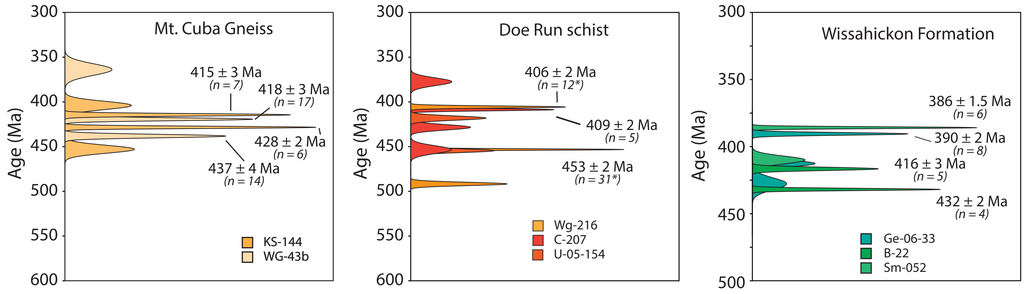
Simplified Geologic Map of the Central Appalachian Piedmont



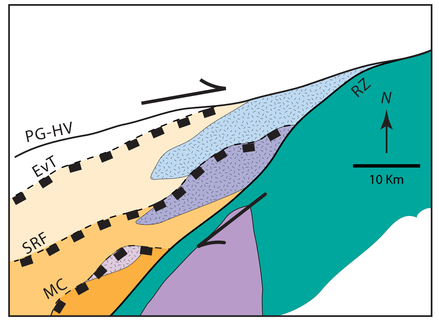
Geologic Map of Southeastern Pennsylvania and Northern Delaware



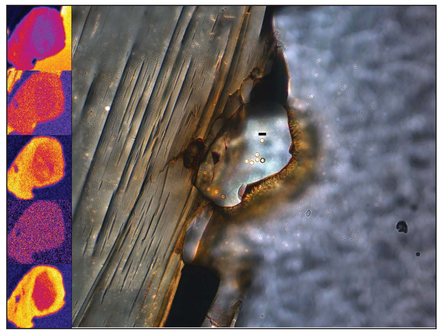
Age of metamorphism

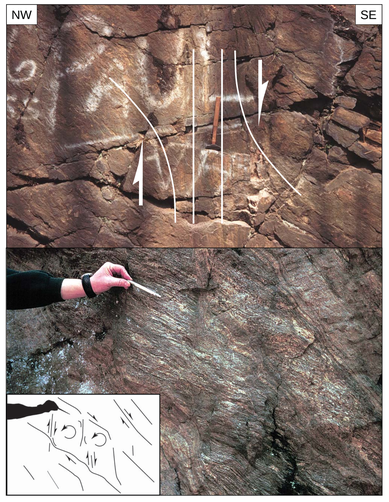


Devonian dextral transtension (?)

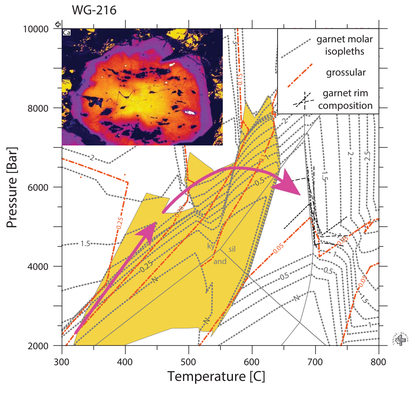


Results of U-Th-total Pb monazite geochronology. This study focuses on rocks of the West Grove Metamorphic Suite, the Doe Run Schist and Mt. Cuba Gneiss, which occur in a series of basement cored nappes bounded by sub-vertical shear zones. The structurally highest MCG in the Mill Creek nappe records the Silurian metamorphism, 424.9 ±0.4 Ma (Aleinikoff et al., 2006) while the structurally lowest West Chester nappe did not attain maximum temperatures until the early Devonian, at 409 Ma. East of the Rosemont shear zone (RZ), metamorphism in the Wissahickon Formation is Middle Devonian. The results shown above are weighted averages of compositional/age domains within a single thin section with 2σ precision. Results with an asterisk(*) are the weighed average of individual spot analyses, performed at RPI (Bosbyshell et al., 2007). All other results were obtained at the UMass Ultrachron lab (Bosbyshell et al., in preparation). The Moacyr monazite consistency standard was analyzed at both labs. Scale bar in image at right is 5 μm.



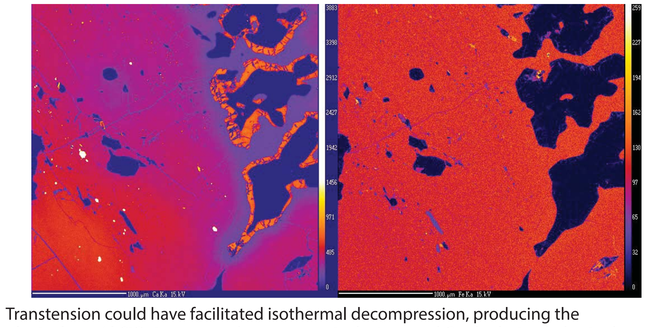


Younger, lower temperature, right-lateral transcurrent motion is well documented in the PGHV and RZ shear zones (Valentino et al., 1994, 1995). We suggest that a change from sinistral to dextral kinematics may have resulted in a transtensional regime. Rosemont shear zone fabrics pictured at left indicate right-lateral, east side down sense of motion.



WG-216

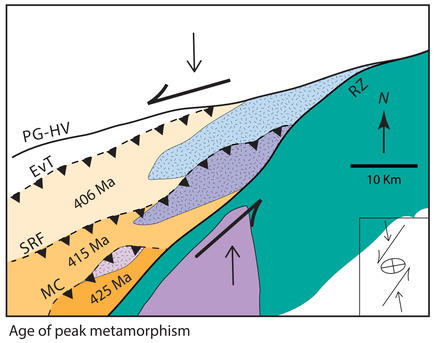
P-T-D-t path - Doe Run Schist. Garnet in the Doe Run Schist is characterized by low-Ca rims, which modeling and textures suggest is the result of resumed garnet growth upon high-temperature staurolite breakdown. This late garnet growth cross-cuts the dominant foliation in some samples, but is wrapped by the foliation in others, indicating that maximum temperature is syn- to post kinematic. Monazite inclusions within the low-Ca garnet rims give an early Devonian age, providing a maximum age for peak temperatures and the cessation of deformation.



Transtension could have facilitated isothermal decompression, producing the plagioclase- Al_2SiO_5 inter growths on quartz inclusions and Ca-depletion halos in the surrounding garnet. Whitney (1991) proposed that similar textures were the result of reactions involving fluid, introduced along fractured in garnet, with aqueous Ca^{+2} as a product. A monazite inclusion along a fracture in the garnet above yielded an age of 399 ±14 Ma (Pyle et al., 2006), which may constrain the timing of the onset of uplift.

Siluro-Devonian sinistral tanspression

The geometry of the thrust sheets in relation to the steeply dipping shear zones is consistent a sinistral transpressive regime. The timing of metamorphism, with peak temperatures attained first in the structurally highest block is interpreted to represent successive stacking of thrust sheets from southeast to northwest with the warmer overriding sheets contributing to the thermal budget of lower sheets. The sinistral shear zone below is in the Mt. Cuba gneiss near the margin of the Rosemont shear zone.



Age of peak metamorphism

Acknowledgments. This work was funded in part by the Pennsylvania Geological Survey and the USGS through the State Map Cooperative Mapping Program and by a grant from the West Chester University College and Arts and Sciences. We thank Julian Allaz, Mike Jercinovic and Mike Williams of the University of Massachusetts Ultrachron lab.

References

Aleinikoff, J.L, Schenck, W. S., Plank, M. O., Srogi, L. A., Fanning, C. M., Kamo, S. L., and Bosbyshell, H., 2006, Deciphering igneous and metamorphic events in high-grade rocks of the Wilmington Complex, Delaware: Morphology, cathodoluminescence and backscattered electron zoning, and SHRIMP U-Pb geochronology of zircon and monazite: Geological Society of America Bulletin, v. 118, p. 39-64.

Bosbyshell, H., Srogi, L., Pyle, J., and Blackmer, G.C., 2007, Preliminary Monazite U-Th-Total Pb Absolute Age Constraints on Crustal Thickening and Siluro-Devonian Dextral Transpression: Central Appalachian Piedmont, SE Pennsylvania [abs.]: Eos (Transactions, American Geophysical Union) v. 88, Fall Meeting Supplement, V23C-1555.

Pyle, J.M., Bosbyshell, H., and Blackmer, G.C., 2006, Refining the metamorphic and tectonic history of the southeastern Pennsylvania Piedmont: Recent results from monazite and zircon geochronology and accessory-phase thermometry, in Pazzaglia, F.J., ed., Excursions in Geology and History: Field Trips in the Middle Atlantic States: Geological Society of America Field Guide 8, p. 83-112.

Hibbard, J.P., van Staal, C.R., and Miller, B.V., 2007, Links among Carolinia, Avalonia, and Ganderia in the Appalachian peri-Gondwanan realm, in Sears, J.W., Harms, T.A., and Evenchick, C.A., eds., Whence the Mountains? Inquiries into the Evolution of Orogenic Systems: A Volume in Honor of Raymond A. Price: Geological Society of America Special Paper 433, p. 291–311, doi: 10.1130/2007.2433(14).

Hibbard, J.P., van Staal, C.R., and Rankin, D.W., 2010, Comparative analysis of the geological evolution of the northern and southern Appalachian orogen: Late Ordovician–Permian, in Tollo, R.P., Bartholomew, M.J., Hibbard, J.P., and Karabinos, P.M., eds., From Rodinia to Pangea: The Lithotectonic Record of the Appalachian Region: Geological Society of America Memoir 206, p. 51–69, doi: 10.1130/2010.1206(03).

Valentino, D.W., Gates, A.E., and Glover, L., III, 1994, Late Paleozoic transcurrent tectonic assembly of the central Appalachian Piedmont: Tectonics, v. 13, p. 110-126.

Whitney, D. L, 1991, Calcium depletion halos and Fe-Mn-Mg zoning around faceted plagioclase inclusions in garnet from a high-grade pelitic gneiss: American Mineralogist, v. 76, p. 493-500.