Geological Society of America
Digital Map and Chart Series DMCH002
2005

Bedrock geology of the West Grove Quadrangle, Pennsylvania-Delaware piedmont

J. Alcock
Department of Environmental Sciences, Pennsylvania State University, Abington, Pennsylvania 19001, USA

ABSTRACT

Three lithotectonic units are exposed across the West Grove Quadrangle in the Pennsylvania-Delaware piedmont. These are mid-Proterozoic gneisses that core the Landenberg, Avondale, and Woodville Massifs, latest Proterozoic to Early Paleozoic metasediments of the Glenarm Series (Setters Formation and Cockeysville Marble) that form the margins of the massifs, and the allocthonous latest Proterozoic to early Paleozoic metasediments of the Wissahickon Formation. Metamorphic and structural discontinuities can be used to establish that each unit has experienced a distinct metamorphic and tectonic history.

Keywords: Pennsylvania-Delaware piedmont, Glenarm Series, Wissahickon Formation, metamorphic discontinuity, structural discontinuity.

INTRODUCTION

Multiple deformational and metamorphic events affecting the Pennsylvania-Delaware piedmont during early Paleozoic plate collision produced a complex regional structure that continues to cause debate amongst geologists working in the area. A key issue of contention is the relationship of metapelites and metapsammites of the Wissahickon Formation to the Cockeysville Marble and Setters Formation, which were originally deposited on the Laurentian continental margin. Historically, the Wissahickon Formation of southeastern Pennsylvania has been considered a member of the Glenarm Supergroup that lies conformably above the Setters Formation and Cockeysville Marble (Knopf and Jonas, 1923; Higgins, 1972; Crowley 1976, among others). This interpretation is challenged by recently identified structural and metamorphic discontinuities at the base of the Wissahickon Formation (Alcock, 1994; Alcock and Wagner, 1995; Plank and Schenck, 1997). The map of the bedrock geologic of the West Grove Quadrangle presented here can be used to identify key locations and relationships among the different map units and supports the interpretation that the Wissahickon Formation in this area is allocthonous, having been thrust across the lower units during Paleozoic plate collision.

Mapping by the author was initiated in an effort to better define metamorphic and structural relationships among the various lithotectonic units exposed in the Pennsylvania-Delaware Piedmont as part of a doctoral thesis (Alcock, 1989) with additional work continuing until 1996. Mapping was conducted at a scale of 1:24,000.

DESCRIPTION OF LITHOLOGIES

Mid-Proterozoic Gneiss

The Landenberg, Avondale, and Woodville massifs are cored by mid-Proterozoic gneisses. The gneiss in this area typically has amphibolite grade metamorphics with hornblende, biotite, and garnet as the most common ferromagnesian minerals. Plagioclase, orthoclase, quartz, and sillimanite are also present. Epidote and muscovite occur as secondary minerals

jea4@psu.edu

Alcock, J., 2005, Bedrock geology of the West Grove Quadrangle, Pennsylvania-Delaware piedmont: Geological Society of America Digital Map and Chart 002, 3 p., doi: 10.1130/2005.DMCH002.

where retrograde reactions have occurred. The gneissic fabric results from compositional banding, most commonly a millimeter-scale layering with tight isoclinal folds. Near the Street Road and Broad Run faults, the fabric of the gneiss becomes mylonitic.

Setters Formation

The Setters Formation consists of quartzite, microcline quartzite, and metapelitic units. Garnet is common in all varieties. Quartzite and microcline quartzite break along foliation to produce Avondale flagstones quarried from the southwest end of the Avondale massif. The metapelitic unit has a schistose fabric created by crenulation of biotite and muscovite-rich layers. The age of the unit is uncertain but is probably Cambrian to Ordovician based on correlation with unmetamorphosed shelf sediments on Proterozoic basement to the north and northwest (Higgins, 1972; Drake et al., 1989; Plank et al., 2000).

Cockeysville Marble

The Cockeysville Marble is an impure dolomitic marble with a gneissic appearance created by compositional layering reflecting original sedimentary differences. Mineral assemblages include Cc-Do-Qtz-Or, Cc-Do-Qtz-Phl, Cc-Do-Tr-Phl, and Cc-Do-Di-Phl (abbreviations after Kretz, 1983). Other minerals include talc, tourmaline, scapolite, titanite, and graphite. Metamorphic grade in the marble increases from north to the south, marked largely by the very limited occurrence of diopside and the more common occurrence of dolomite + quartz in stable association near Avondale. The age of the unit is uncertain but is probably Cambrian to Ordovician based on correlation with unmetamorphosed shelf sediments on Proterozoic basement to the north and northwest (Higgins, 1972; Drake et al., 1989; Plank et al., 2000).

Wissahickon Formation

Assemblages found in the pelitic to semi-pelitic to psammitic schist and gneiss of the Wissahickon Formation include Mu-Bi-Qtz-Pl-Grt, Mu-Bi-Grt-Qtz-Pl-Ky-St, Mu-Bi-Grt-Qtz-Pl-Sil (+secondary Ky ± St), and Or-Sil-Bi-Grt-Qtz-Pl. Metamorphic grade increases from northwest to southeast, and the approximate positions of mineral isograds are shown. The age of the formation is uncertain. Monazite U-Pb ages that range from ca. 480 Ma (Crawford et al., 2001) indicate an Ordovician or earlier deposition.

Between Landenberg and Avondale, conformable bodies of amphibolite are present and range in thickness to several meters. The original structural relationship of the amphibolite layers to the metasediments is uncertain as the amphibolites may have been reoriented during deformation. Pegmatite also occurs as small irregular bodies and dikes. Neither amphibolite nor pegmatite bodies have been separated as distinct members of the Wissahickon Formation because outcrop is typically limited and the true extent of the bodies cannot be determined.

STRUCTURAL RELATIONSHIPS

Folding—Recumbent Isoclines

Tight recumbent isoclinal folds affect the mid-Proterozoic gneiss, Setters Formation, and Cockeysville Marble. Fold axes plunge moderately to the south. The overturned limb of the fold is exposed is several quarries along the north side of the Avondale massif near Willowdale in the Kennett Square quadrangle to the east of the West Grove quadrangle. Near continuous occurrence of the Setters Formation as outcrop and more commonly as float suggest that marble and quartzite dip south beneath the gneiss of the massif along its north edge. Similarly, fabric in marble and quartzite in the area near Baker indicate a stratigraphic reversal with marble dipping beneath quartzite.

Overturned stratigraphic relationships are also apparent in small quarries south of Landenberg where marble dips to the north beneath a pelitic member of the Setters Formation, which in turns dips to the north beneath mid-Proterozoic gneiss.

Open, Upright Folds

The isoclines have been folded by later upright, open folds that involve all three lithotectonic units. The most significant of these folds is the arching of Woodville massif along NE-SW axis. Subsidiary folds along its southern flank create repetition of units and the irregular outline of contact at the base of the Wissahickon Formation between Avondale and the Street Road fault north of Chatham. Approximate positions of axial traces of the folds are shown on the map.

Faults—The Doe Run Thrust

The Doe Run thrust is inferred from structural and metamorphic discontinuities. Structural discontinuities are most apparent along the western end of the Avondale massif where the Wissahickon Formation crosscuts a number of contacts between marble and quartzite. In addition, the strong topographic control on the occurrence of the Wissahickon Formation suggests a low angle contact with the rocks beneath, quite distinct from the tight recumbent folding that controls the outcrop pattern of the marble and quartzite.

South of Landenberg, metamorphic conditions inferred from mineral assemblages in the Cockeysville Marble and Wissahickon Formation imply a significant metamorphic discontinuity, probably in excess of 100 °C (Alcock and Wagner, 1995). A smaller metamorphic discontinuity is inferred at Avondale from mineral assemblages in the Cockeysville Marble and the Wissahickon Formation and from the absence of sillimanite in the pelitic member of the Setters Formation where quartz and muscovite occur together in stable association.

Basement-Cored Reverse Faults

Two basement-cored reverse faults are mapped. The Broad Run fault, named herein, occurs along the north limb of the exposure of mid-Proterozoic gneiss south of Landenberg and lifts gneiss, marble, and uppermost amphibolite facies gneiss of the Wissahickon Formation onto a somewhat lower-grade Wissahickon gneiss and schist. The second, the Street Road fault, extends along the northern edge of the Woodville Massif and can be traced to the eastern end of the Avondale Massif north of Media, Pennsylvania. It lifts gneiss, quartzite, marble, and schist onto similar lithologies but with distinct structural relationships of the Doe Run Window (Alcock, 1994). In the vicinity of both thrusts, the mid-Proterozoic gneiss becomes mylonitic.

ACKNOWLEDGMENTS

Mary Emma Wagner provided valuable encouragement and advice during the mapping. I also appreciate the suggestions for improvement made by Joseph Andrew and Douglas Walker, who reviewed an earlier version of the map. Financial support for the project was provided by the Pennsylvania Department of Environmental Resources, the University of Pennsylvania, and the Pennsylvania State University.

REFERENCES CITED

(With additional references of historical and scientific importance to the Geologic Map of the West Grove Quadrangle.)

Alcock, J.E., 1989, Tectonic units in the Pennsylvania-Delaware Piedmont: Evidence from regional metamorphism and structure [Ph.D. thesis]: University of Pennsylvania, 251 p.

Alcock, J., 1994, The discordant Doe Run thrust: Implications for stratigraphy and structure in the Glenarm Supergroup, southeastern Pennsylvania Piedmont: Geological Society of America Bulletin, v. 106, p. 932–941, doi: 10.1130/0016-7606(1994)106<0932:TDDRTI>2.3.CO;2.

Alcock, J., and Wagner, M.E., 1995, Metamorphic discontinuities in the Pennsylvania-Delaware Piedmont: evidence for early Paleozoic assembly: Canadian Journal of Earth Sciences, v. 32, p. 686–698.

Bailey, E.B., and Mackin, H., 1937, Recumbent folding in the Pennsylvania Piedmont; preliminary statement: American Journal of Science, v. 33, p. 187–190.

Bascom, F., and Stose, G.W., 1932, Description of the Coatesville and West Chester Quadrangles: U.S. Geological Survey Atlas, Folio #223, 15 p.

Bliss, E.F., and Jonas, A.I., 1916, Relation of the Wissahickon mica gneiss to the Shenandoah Limestone and Octararo schist of the Doe Run and Avondale region, Chester County, Pennsylvania: U.S. Geological Survey Professional Paper 98-B, 34 p.

Crawford, M.L., Bosbyshell, H., and Williams, M.L., 2001, Electron microprobe age mapping and dating of monazite; deconvoluting polyphase Paleozoic tectonism in the Central Appalachians: Geological Society of America Abstracts with Programs, v. 33, no.1, p. 82.

Crowley, W.P., 1976, The geology of the crystalline rocks near Baltimore and its bearing on the evolution of the Eastern Maryland Piedmont: Maryland Geological Survey Report of Investigations No. 27, 40 p.

Drake, A.A., Sinha, A.K., Laird, J., and Guy, R.E., 1989, The Taconic orogen, *in* Hatcher, R.D., Jr., Thomas, W.A., and Viele, G.W., eds., The Appalachian-Ouachita Orogen in the United States: Boulder, Colorado, Geological Society of America, Geology of North America, v. F-2, p. 110–177.

Higgins, M.W., 1972, Age, origin, regional relations, and nomenclature of the Glenarm Series, Central Appalachian Piedmont: A reinterpretation: Geological Society of America Bulletin, v. 83, p. 989–1026.

Kretz, R., 1983, Symbols for rock-forming minerals: American Mineralogist, v. 68, p. 277–279.

Knopf, E.B., and Jonas, A. I., 1923, Stratigraphy of the crystalline schists of Pennsylvania and Maryland: American Journal of Sciences, 5th Series, v. 5, p. 40–62.

McKinstry, H.E., 1949, Mineral isograds in southeastern Pennsylvania: American Mineralogist, v. 34, p. 874–892.

McKinstry, H., 1961, Structure of the Glenarm Series in Chester County, Pennsylvania: Geological Society of America Bulletin, v. 72, p. 557–578.

Plank, M.O., and Schenck, W.S., 1997, The Setters Formation in the Pleasant Hill Valley, Delaware: Metamorphism and structure, Report of Investigations No, 56: Delaware Geologic Survey, Newark, Delaware, v. 15, p. 99.

Plank, M.O., Schenck, W.S., and Srogi, L., 2000, Bedrock geologic map of the piedmont of Delaware and adjacent Pennsylvania, Report of Investigations No. 59: Delaware Geologic Survey, Newark, Delaware, 52 p.

Schenck, W.S., Plank, M.O., and Srogi, L., 2000, Bedrock geologic map of the piedmont of Delaware and adjacent Pennsylvania: Delaware Geologic Survey, Geologic Map Series No. 10, scale 1:36,000.