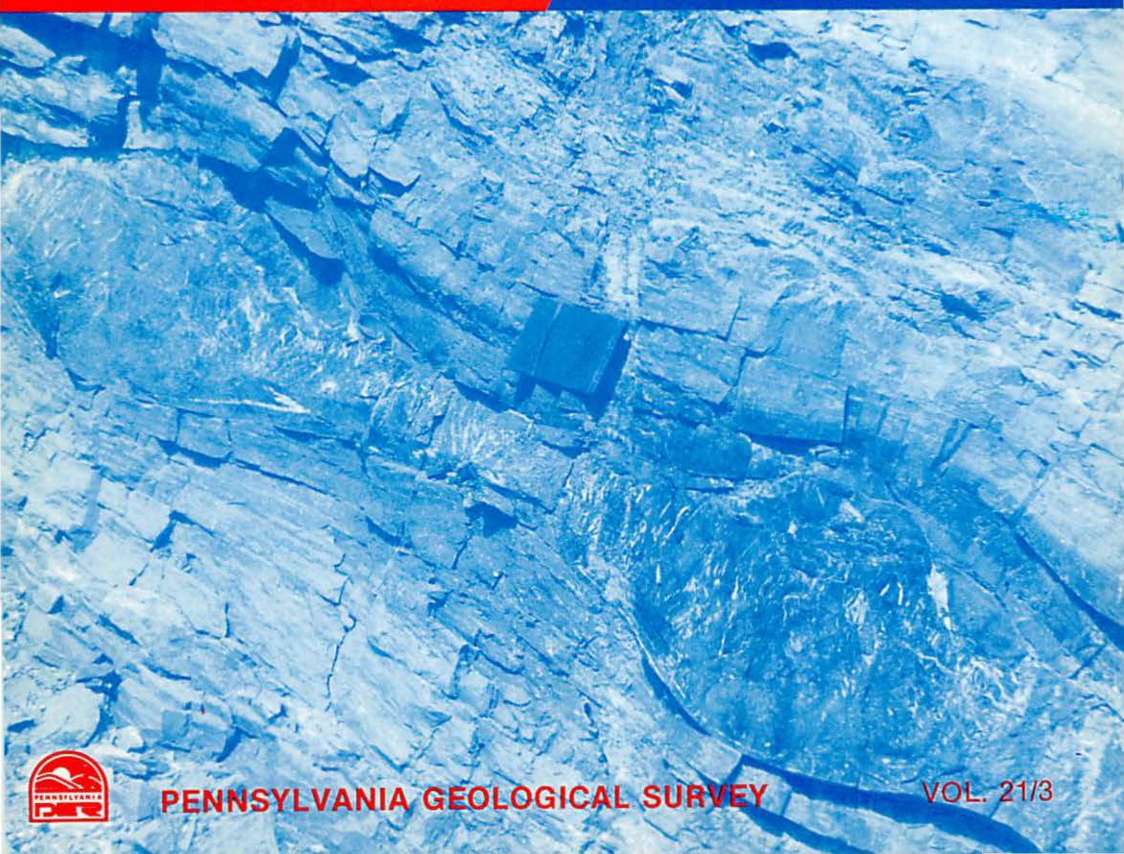
PENNSYLVANIA GEOLOGY



PENNSYLVANIA GEOLOGICAL SURVEY VOL. 21/3

COMMONWEALTH OF PENNSYLVANIA
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TOPOGRAPHIC AND GEOLOGIC SURVEY
Donald M. Hoskins, Director

CONTENTS

ON THE COVER: Boudinage in the Union quarry at Rheems, in the northwest part of Lancaster County. Bedding dips moderately to the right. Most of the beds are limestones of the Lower Ordovician Epler Formation; the bed in the center filled with numerous white calcite veins is dolomite. These rocks have been greatly extended parallel to bedding. The limestones were ductile and thinned uniformly, whereas the dolomite, being more brittle, was extended inhomogeneously and developed boudinage structure. Where the extension was concentrated, the dolomite bed became very thin; the rocks between these necks underwent little extension and thus retained nearly their original thickness. The notebook is 21 cm long. Photograph by Rodger T. Faill.

PENNSYLVANIA GEOLOGY is published bimonthly by the Bureau of Topographic and Geologic Survey, Pennsylvania Department of Environmental Resources, P. O. Box 2357, Harrisburg, Pennsylvania 17105.
Editors, Christine M. Dodge and Donald M. Hoskins.
Articles may be reprinted from this magazine if credit is given to the Topographic and Geologic Survey.

VOL. 21, NO. 3 **JUNE 1990**

The Beneficial Effects of Natural Disasters

In a recent article published in the *Journal of Irreproducible Results*, the author, Craig Bradley, with tongue in cheek, discusses the "challenging task of determining the beneficial effects of a major earthquake along the San Andreas Fault." While his article (volume 35, number 2, page 2) is humorous, it also has a very serious message, which is, he suggests, "to discover the good side of circumstances that cause only despair to others." Ben Franklin, a Pennsylvanian of some note, said it also in his adage, "the things that hurt instruct."

The "good side" is that each natural disaster teaches and reteaches us that only through attention to natural earth features such as steep colluvial slopes, areas of carbonate bedrock, and floodplains, and the dynamic earth systems that affect them, will we be able to safely design and build structures on which humans depend for daily existence. This requires data provided through careful, detailed, and accurate mapping of Pennsylvania's land surface and its weathered and unweathered bedrock. Knowledge of the three-dimensional relationships of Pennsylvania's land surface and its subsurface rocks, as well as their geophysical and geochemical characteristics, is critical for analysis.

Although we do not have to calculate the "beneficial" effects of a California-style earthquake for Pennsylvania, we do have to include in all construction plans and designs the likelihood of the occurrence of sinkhole collapse, landslides, or flooding. To ignore the "good side" lesson of natural disasters is folly. Similarly, we should cease considering such events as "acts of God." They are not; none are unique and all are frequently repeated in predictable locations. Pennsylvania's citizens and businesses, local governments, and the Commonwealth all repeatedly pay a large annual cost for ignoring the "beneficial effects of natural disaster" lesson, the lesson recognized by Franklin early in the development of Pennsylvania.

Donald M. Hoskins

Donald M. Hoskins
State Geologist

OVERHEAD PROTECTION

Pennsylvania's Mineral Industry Contribution

by S. W. Berkheiser, Jr., and R. C. Smith, II
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Generally, industrial minerals are like a good dog. They are quiet, resolute, trustworthy, economical, and do their duty without a lot of backlash. Most of the time, we are not even aware of the presence of industrial minerals, but they make life easier, more pleasant, and more enjoyable. Such is the case with roofing granules, those tiny, colored, ceramic-coated rock particles that are embedded in shingles. Collectively, they protect a great number of our houses from the effects of rain, sleet, and snow. This article concerns the operation of GAF Corporation, a member of Pennsylvania's mineral industry that began producing naturally colored roofing granules from metabasalt and metarhyolite for use in asphalt-based shingles in the 1920's. The plant and now-abandoned underground metabasalt mine that GAF purchased from The Blue Mountain Stone Company are located about 0.4 mile northwest of Gladhill, Pennsylvania, in southwestern Adams County.

HISTORY. Fiberglass-based shingles, embedded with artificially colored roofing granules, have evolved into the premier economical, fire-resistant, attractive roofing material used by the construction industry. The development of this complex, high-technology roof covering, now typically guaranteed to last 20 to 25 years, required years of research and experimentation. Humble beginnings, as early as 1780, involved attempts to find economical alternatives to slate, wood, and metal by using burlap saturated with pitch or tar (Jewett and others, 1983). Needless to say, these early attempts were far from satisfactory because they deteriorated rapidly and were expensive, difficult to work with, and ugly. They were also a major fire hazard!

A roof should not only be waterproof, but also fire resistant to help prevent fires from spreading from building to building. Early searches for suitable fire-resistant materials with which to armor the asphalt-saturated felt-base roofing materials led to the use of naturally colored source rocks. Initially, multicolored slate from New England was popular. The somber color of Pennsylvania's black and blue-gray slate led some producers to look to the greenstone and serpentine belts to find a more pleasing, nonfading green color (Stone, 1923). Among the many materials that have been tried over the years in the search for aesthetically pleasing roofing armor are silica sand, vein quartz, novaculite, feldspar, mica, greenstone, talc, glass, slag, basalt, granite, rhyolite, oyster shells, crushed bricks and tiles, and white porcelain (Jewett and others, 1983).

In the 1930's, the development of ceramic coatings changed the complexity and specifications of premium roofing granules by eliminating source rock color as a major consideration. According to Jewett and others (1983), the desirable properties for potential deposits of roofing granules today include the following:

(1) Resistance to weathering (eliminating carbonates and unsound rock from consideration);
(2) Adaptability to the coloring process (eliminating soluble rock and rock that does not have a porous surface);
(3) Uniformity of the deposit (assuring consistency of the finished product over a long period of time);
(4) Sufficient tonnage (allowing enough potential production over time to ensure a reasonable return on the initial capital investment);
(5) Low porosity (to prevent excessive absorption of coating chemicals, which could prove costly, or excessive adsorption of water, which might cause freeze-thaw deterioration);
(6) Opacity to ultraviolet light (to protect the base material from attack by solar radiation);
(7) Toughness (to minimize attrition); and
(8) Equidimensional fracturing upon crushing (together with blending, this assures a uniform color when the roof is viewed from different angles).

MINING. The West Ridge quarry of GAF is located on a northeast-southwest-trending ridge north of the Gladhill plant (Figure 1). The ore is mined from the Catoctin Formation, which here consists of a relatively uniform greenish-gray basalt metamorphosed to the green-

Figure 1. Southwest-looking view of the West Ridge quarry of GAF Corporation, showing the five levels of bench development. Faint southeast-dipping cleavage is visible in the near faces.

schist facies. Massive and amygdaloidal metabasalts are present in the area. Quarry control includes monitoring to avoid areas of high concentrations of iron, quartz (which has a smooth, nonporous surface and is transparent to ultraviolet light), epidote (which is hard to crush), and native copper. In addition, crushability tests for the minus 10 mesh (2.0 mm) to plus 35 mesh (0.5 mm) size fraction are closely monitored for minimum waste and maximum cubical particle shape (Nelson, 1968, and personal communication, 1988). Currently, GAF is developing a fifth quarry level using 40-foot-high quarry faces. Approximately 40 coreholes have helped to define a mining plan for potential quarrying down to a seventh level.

The Catoctin Formation is a series of metabasalts, phyllites, and metarhyolites located in the Blue Ridge physiographic province of Pennsylvania (Fauth, 1978). According to Badger and others (1988), these rocks are approximately 570 million years old, making them Late Precambrian in age. This sequence is more or less continuous to the south through Maryland and Virginia. The geologic setting has been interpreted to represent a series of extrusive igneous flows (locally submarine) and tuffs, associated with extensional rifting of continental plates that resulted in the opening of the Iapetus Ocean basin (Badger and others, 1988). Preliminary analyses of Catoctin metabasalts from the Gladhill area are listed in Table 1. Comparison of some trace-element ratios with those from relatively young basalts that are known to have formed in particular environments, such as an island-arc environment, along a mid-ocean ridge, or within a continental plate, suggests that the Catoctin metabasalt in this area formed within a plate.

Table 1. *Preliminary Analyses of Two Samples of Catoctin Metabasalt from the Gladhill Area, Adams County*

(Quantities are percentages)

	Sample 1	*Sample 2*
SiO_2	44.06	44.41
Al_2O_3	15.04	17.26
Fe_2O_3	14.20	13.41
CaO	9.85	8.49
MgO	6.92	7.73
Na_2O	2.35	1.79
K_2O	.31	.84
TiO_2	2.02	1.64
MnO	.21	.19
P_2O_5	.25	.16
Total	95.21	95.92

MANUFACTURING. Although the natural color, transportation network, and proximity to potential markets were original factors in GAF's site selection process in the 1920's, before the development of ceramic coatings, the green metabasalt of the Catoctin Formation is still quarried because of its adaptability to the silicate-clay coloring process (Figure 2). The quarry rock is initially reduced in a jaw crusher and further reduced in a series of gyratory crushers. Roll crushers prepare the final gradation of minus 10 mesh to plus 35 mesh, which is stored

Figure 2. Northwest-looking view of the roofing-granule manufacturing complex of GAF Corporation. The crushing and sizing plant is in the foreground, and the coloring plant is higher on the hill in the background.

in silos. The ceramic coatings, which are based on a sodium silicate flux and a kaolin binder combined with inorganic pigments, are applied in a rotary mixer. The mixture is fired in a rotary kiln. The cooled and coated granules are screened again to remove agglomerates and are stored in silos. Fifteen different colors of granules are manufactured at Gladhill. There are two production lines in the coloring plant, and approximately 80 percent of all granules sold or used are color coated. The natural granules are used primarily for the headlap (covered) portion of the shingle. The newer fiberglass-based shingles require more granules than the older asphalt-felt-based shingles.

MARKETING. The primary product of the Gladhill operation is artificially colored roofing granules manufactured for shingle coatings. Most shingles are coated with a blend of several distinct granule colors. Earth tones have been in vogue for the past decade, whereas reflective, light hues are popular in warm climates. Most of the prepared granules are transported to GAF's shingle-manufacturing plants in Maryland and Massachusetts by 100-ton bulk railcars and to a lesser extent by 25-ton haul trucks. Granules are also sold to competing shingle-manufacturing plants in Delaware, Georgia, Maryland, New Jersey, North Carolina, and Pennsylvania.

The fine-grained by-product, or "tails," of this operation is put to a number of innovative uses. Some is used as a mineral filler in the shingle base and as an inert mineral filler in portland cement. It also finds use in walkways in the Gettysburg National Military Park, as colorants in the manufacture of bricks, and in cushions supporting pipelines and underground storage tanks. In what may be one of the most surprising and innovative uses, binder is added to sized by-product material, and the mixture is used as a 6-inch-thick top dressing for clay-based tennis courts.

GAF Corporation is another good example of the many industrial-mineral producers that work behind the scenes to contribute to the improvement of our way of life while collectively contributing more than $1 billion annually to Pennsylvania's economy.

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Geologic Structures and Metamorphism: Mapping the Elusive Isograds in the Pennsylvania Piedmont

by David W. Valentino and Rodger T. Faill
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INTRODUCTION. Many of the rocks in the Piedmont province in southeastern Pennsylvania were once hot, and their minerals show it. Beginning as shales, sandstones, graywackes, and various other rock types, they were progressively buried by younger sediments, or tectonically covered by large thrust sheets. The heat and pressure during this deep burial transformed the clays and rock fragments into entirely new assemblages of minerals—they were metamorphosed and deformed. Erosion over the ensuing millions of years has returned these rocks to the surface where we can observe them. They tell quite a story!

As a rock is heated, it undergoes a sequence of mineralogic changes, which are grouped into three facies: greenschist, amphibolite, and granulite. Each facies represents an approximate range of temperatures and pressures within which a particular assemblage of minerals forms or exists (Figure 1). By identifying the minerals in a specific rock, the locality where the rock occurs can be assigned to the appropriate facies; and by assembling locality identifications from across the Piedmont, we obtain a map of metamorphic zones (Figure 2). This map shows the areas that have undergone only greenschist (low-grade) metamorphism as well as the areas at higher grades. Each of the lines (isograds) separating adjacent areas is defined by the first occurrence of the higher grade mineral when mapping from areas of lower to higher grade. The isograds are also defined by the disappearance of the higher grade mineral when mapping from areas of higher grade to areas of lower grade. Thus the biotite-garnet isograd (Figure 2) represents the first discovery of garnet during field mapping in the direction of increasing metamorphic grade.

The rocks of the highest metamorphic grade, the granulite facies, are present only in the eastern Piedmont. These areas are generally surrounded by rocks at the next lower grade, the amphibolite facies; a tongue of amphibolite facies rocks also extends across the western

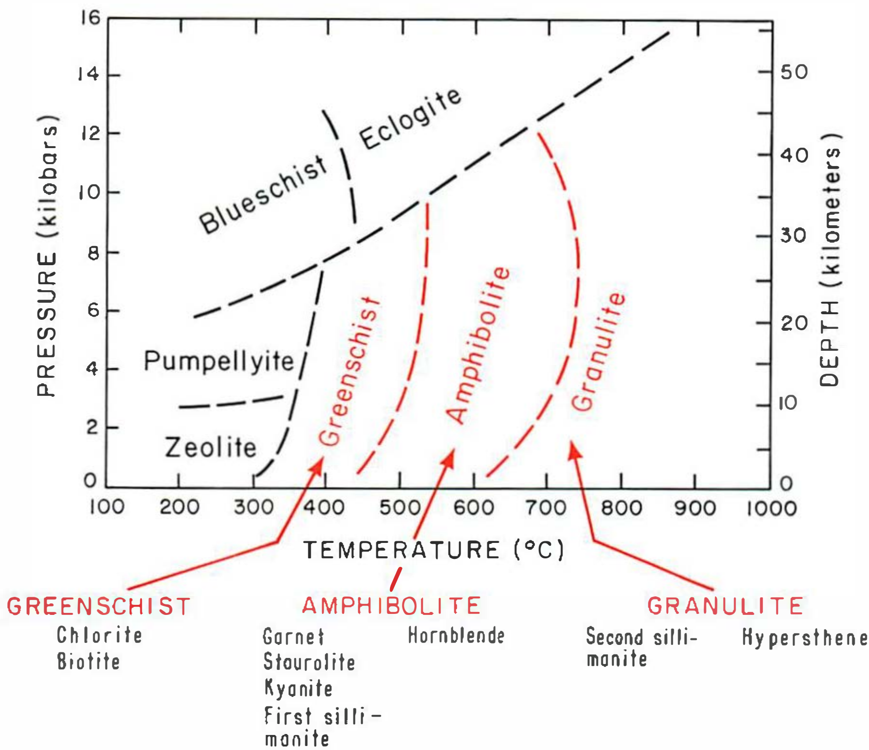


Figure 1. Diagram showing the relative positions of the various metamorphic facies with respect to approximate temperature and pressure, and a listing of metamorphic minerals associated with the metamorphic facies mapped during this investigation. Modified from Dietrich and others (1982).

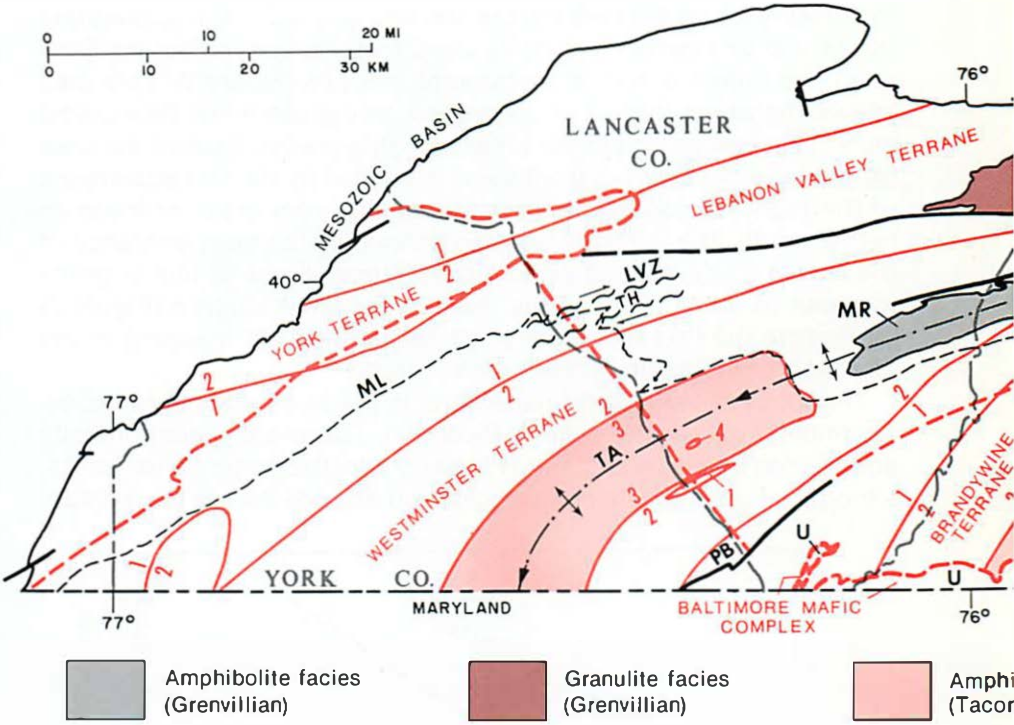
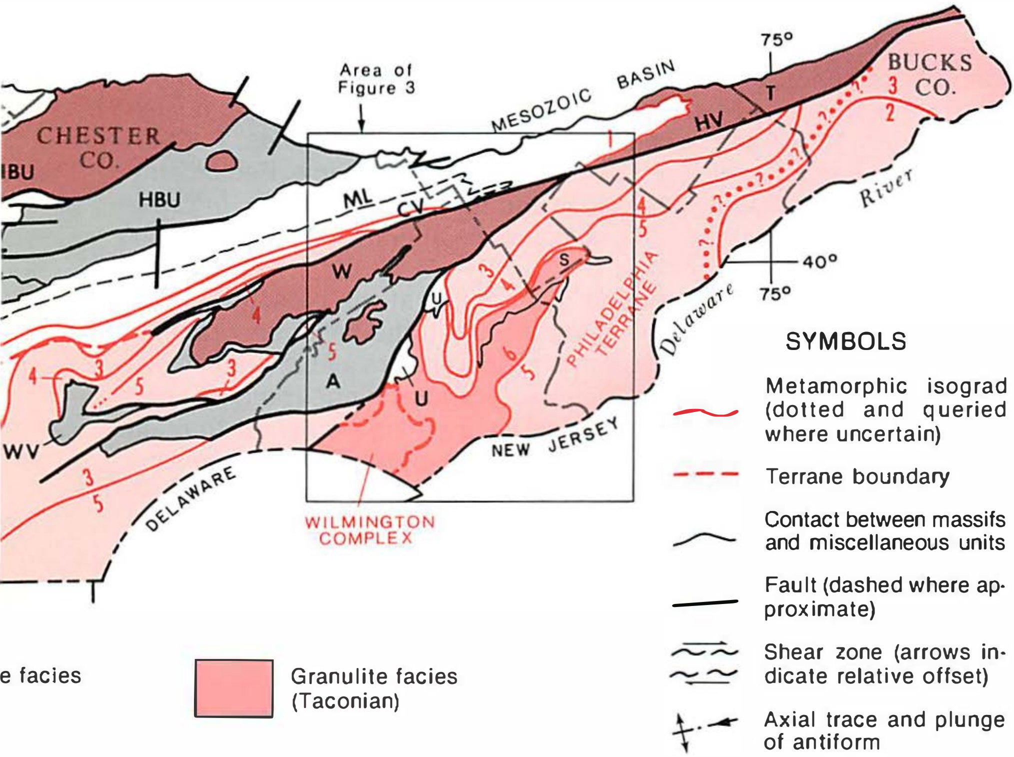


Figure 2. Map of the Pennsylvania Piedmont showing structures, terrane boundari
Structures: CV-HV, Cream Valley-Huntingdon Valley fault zone; LVZ, Lancaster Valle
Turkey Hill shear zone.
Grenvillian massifs: A, Avondale massif; HBU, Honey Brook Upland massif; MR, M
Miscellaneous units: S, Springfield gneiss; U, ultramafic rocks.
Minerals that define isograds: 1, chlorite; 2, biotite; 3, garnet; 4, kyanite; 5, first sil

Piedmont. The remaining areas, in both the eastern and western Piedmont, are at the greenschist facies.

But the story is not quite as simple as the map suggests. One metamorphism affecting all of the Piedmont rocks cannot explain all of the features on the map; rather, we find that four metamorphic episodes have occurred, each one quite different, and each affecting different parts of the Piedmont.

METAMORPHIC EPISODES. *Grenvillian Metamorphism (M1).* The Grenville terrane contains evidence for the oldest metamorphism, which occurred about 1,000 million years ago (Ma) (Grauert and Wagner, 1975) and is represented by several separate massifs: the Honey Brook Upland, Mine Ridge, Trenton, West Chester, Avondale, and Woodville massifs. The rocks of all of these bodies were meta-



Grenvillian massifs, and metamorphic isograds.
tonite zone; ML, Martic Line; PB, Peach Bottom structure; TA, Tucquan antiform; TH,

Ridge massif; T, Trenton massif; W, West Chester massif; WV, Woodville massif.

nite; 6, second sillimanite.

morphosed (M1) during the Grenvillian orogeny (Wagner and Crawford, 1975; Crawford and Hoersch, 1984; Hoersch and Crawford, 1988), and most of the rocks were metamorphosed to granulite facies (Figure 1), except for the rocks of Mine Ridge and the southern half of the Honey Brook Upland, which only reached amphibolite facies (Crawford and Hoersch, 1984; Hoersch and Crawford, 1988).

Taconian Metamorphism (M2). The metamorphism produced by the Taconian orogeny (dated at approximately 440 Ma by Grauert and Wagner, 1975) affected all of the Piedmont rocks, albeit to differing extents and grades. During this orogeny, diverse terranes (the Lebanon Valley, York, Westminster, Brandywine, and Philadelphia terranes, the Wilmington Complex, and the Grenvillian massifs (Faill and MacLachlan, 1989); see Figure 2) were emplaced in the present Piedmont province, generally in the relative positions they occupy today. The elevated temperatures that accompanied the Taconian orogeny metamorphosed all of the rocks involved, but the metamorphism was not uniform across the Piedmont. The range of metamorphic grades extends from lower greenschist to upper amphibolite facies. Furthermore, this metamorphic episode persisted for a long time. Radiometric ages, which represent dates when the rocks were cooling, indicate that this episode lasted for 100 million years after the peak of the Taconian orogeny.

The occurrence of the higher grade rocks at the present surface is a consequence of tectonism that followed the Taconian orogeny. For example, Taconian metamorphic isograds are symmetrically disposed on either side of the Tucquan antiform hinge, ranging from garnet grade (locally kyanite grade) in the hinge outward through biotite zones (Faill and Valentino, 1989). The tectonism responsible for this antiform has been dated at 320 Ma (Lapham and Basset, 1964) by means of the associated retrograde greenschist facies metamorphism in the limbs of the antiform. This pattern suggests that (1) the Taconian isograds continued over the crest of the Tucquan antiform; and (2) the original Taconian metamorphic isograd surfaces were probably near horizontal prior to post-Taconic uplift.

Southwest of the Tucquan antiform is a broad-trending zone of lower greenschist facies (chlorite-grade) schist and phyllite that extends across southern Lancaster County and southwestern Chester County, within which lies the Peach Bottom "syncline." This chlorite-grade zone becomes narrower to the east, occupying only the Chester Valley and South Valley Hills in central Chester County. The metamorphic gradient south of this chlorite zone becomes steeper to the east (the isograds become closer together), a trend that continues farther eastward into Montgomery County.

Southward and eastward, around the Brandywine massifs, the metamorphic grade increases to the kyanite zone of the amphibolite facies in the rocks closest to the Precambrian massifs. This increase in grade through progressively older rocks is probably a consequence of deeper burial, but the Taconian tectonism likely supplied the additional heat that enhanced the metamorphic grade. No such similar increase has been observed surrounding the Honey Brook massif, although some of the rocks adjacent to Mine Ridge were elevated to the lower amphibolite facies (garnet grade; areas are too small to be shown on Figure 2).

The highest grade rocks in the Philadelphia terrane follow a northeast trend that includes the Springfield gneiss. Metamorphic grade decreases to the northwest and east, to as low as upper greenschist facies east of Philadelphia.

Metamorphism of the Wilmington Complex (M3). The Wilmington Complex (a lower portion of an island arc) was thrust over the Philadelphia and Brandywine terranes, probably during the early stages of the Taconian orogeny (Wagner and Srogi, 1987). Because the complex was already hot, it and the immediately surrounding rocks were elevated to granulite facies (Figure 3). This effect decreased away from the complex, so that at some distance the metamorphism resulting from the emplacement of the complex merged with the Taconian metamorphism and they became indistinguishable.

Retrograde Metamorphism (M4). A probably long period of multiple episodes of retrograde metamorphism followed the largely concurrent Taconian and Wilmington Complex metamorphisms (M2 and M3). Retrograde metamorphism occurred where the rocks (previously metamorphosed during the Grenvillian or Taconian orogenies) were deformed in post-Taconian shear and tectonite zones (Rosemont, Crum Creek, Cream Valley-Huntingdon Valley, and Lancaster Valley). Metamorphic conditions accompanying the formation of these structures allowed for the growth of new lower grade minerals at the expense of the higher grade minerals primarily within the zones of deformation. Therefore, each retrograde episode generally represents a tectonic activity following the peak of Taconian metamorphism, in which deformation allowed for reequilibration of the mineral assemblages under conditions of lower temperature and/or pressure.

The earliest episode (M4a) centered on the Rosemont and Crum Creek shear zones (Valentino, 1988; Valentino, Richard, 1989). Across both of these zones, the Taconian isograds have been severely deflected (Wyckoff, 1952), indicating considerable retrograde metamorphism and post-Taconic offset associated with the zones (Figure 3). Wagner and Crawford (1975) recognized an amphibolite facies retrogression that accompanied mylonite development in the granulite-grade gneisses along the northern edge of the West Chester massif, adjacent to the Cream Valley fault zone (Figure 3).

The broad chlorite-grade zone in southern Lancaster County (Figure 2) continues eastward across eastern Chester County and Montgomery and Bucks Counties as a narrow chlorite-grade zone bounded on the south by the Cream Valley and Huntingdon Valley faults. It has been proposed that this narrow eastern part of the zone (in Chester Valley and the South Valley Hills) represents a later, second episode of retrograde metamorphism (M4b) concentrated along an east-northeast-striking, steeply dipping shear zone (Myer and others, 1985; Hill, 1989). The steep metamorphic gradient just to the south was probably generated during the first retrograde episode (M4a), but the cutoff of isograds by the Cream Valley fault movements may have been coincident with the shearzone movements and associated green-

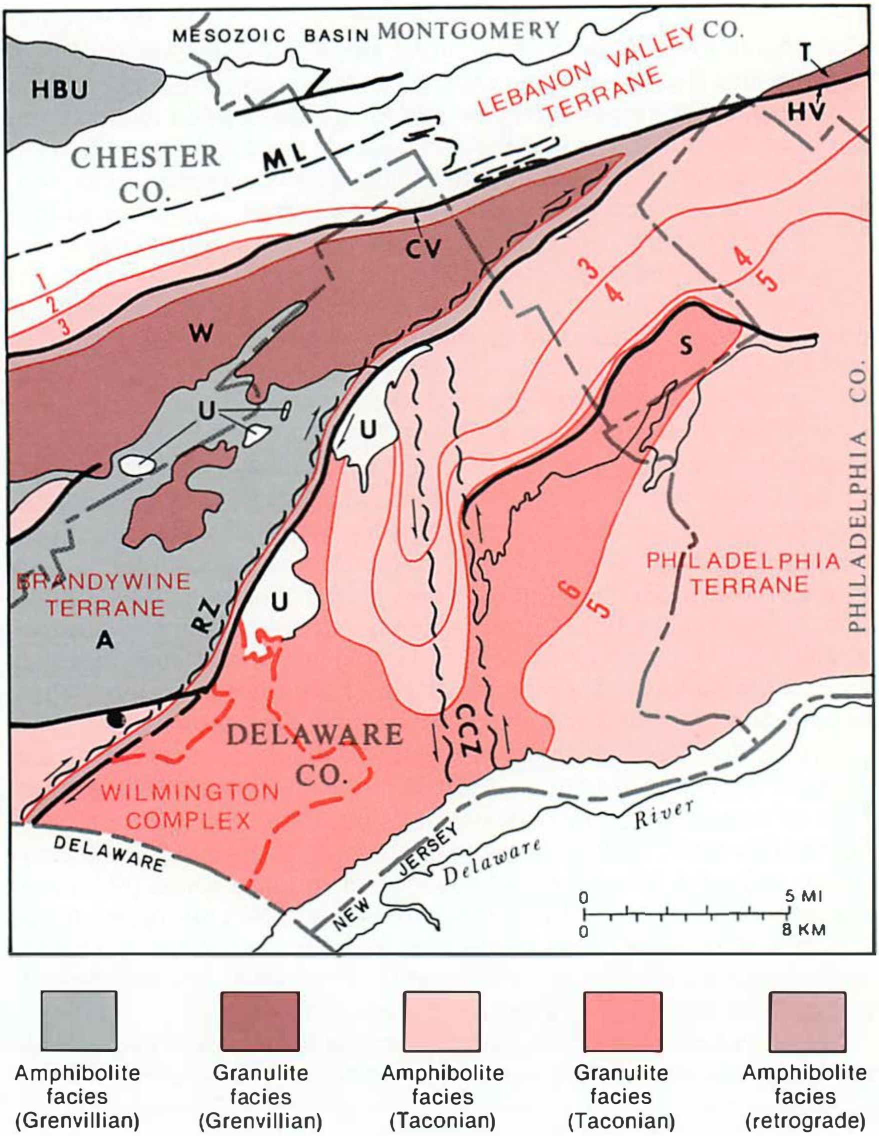


Figure 3. Map of the area west of Philadelphia showing the local structures, metamorphic isograds, terrane boundaries, and Grenvillian massifs. Structures: CCZ, Crum Creek shear zone; RZ, Rosemont shear zone. Refer to Figure 2 for an explanation of the other labels and symbols.

schist retrograde metamorphism. Whether or not this retrograde metamorphism continued southwestward, following the chlorite zone across southern Lancaster County, is simply not known at this time.

A third episode of retrograde metamorphism (M4c) is evident in the western Piedmont of Pennsylvania, in the vicinity of the Susquehanna River. The chlorite-grade zone on the north limb of the Tucquan antiform is actually retrograde from Taconian biotite grade. This broad zone of chlorite retrogression coincides with the Lancaster Valley tectonite zone (Valentino and MacLachlan, 1990) and the Turkey Hill shear zone, in which the north limb of the Tucquan antiform has been sheared (Valentino, 1989, 1990). Correlation of this retrograde zone with the Lancaster Valley tectonite zone and Turkey Hill shear zone indicates a post-Taconian age for these structures, and the deformation is probably synchronous with the differential uplift (Freedman and others, 1964) that produced the Tucquan antiform.

CONCLUSION. Compilation of published and new metamorphic data to produce an isograd map for the Piedmont province of Pennsylvania has revealed numerous structural aspects of the geology, as previously discussed. Recognition of the close relationship between metamorphic episodes and structures has enabled us to better correlate structures with the numerous orogenic episodes that occurred in the central Appalachian orogenic belt.

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NEW PUBLICATIONS OF THE PENNSYLVANIA GEOLOGICAL SURVEY

OIL AND GAS DEVELOPMENTS IN PENNSYLVANIA IN 1988

The latest report on the oil and gas industries in Pennsylvania provides valuable information to members of these industries, academia, and the general public. Data on production, reserve estimates, drilling and completions, and exploratory and development activities are presented by authors John A. Harper and Cheryl L. Cozart in tables and graphs which are both understandable and comprehensive. The "why's" for the 14.9 percent decline in oil production from 1987 to 1988 (3,301,763 to 2,807,003 barrels) are discussed, as are the reasons for the 2.3 percent upswing in gas production (163,318 to 167,089 million cubic feet) during the same time period.

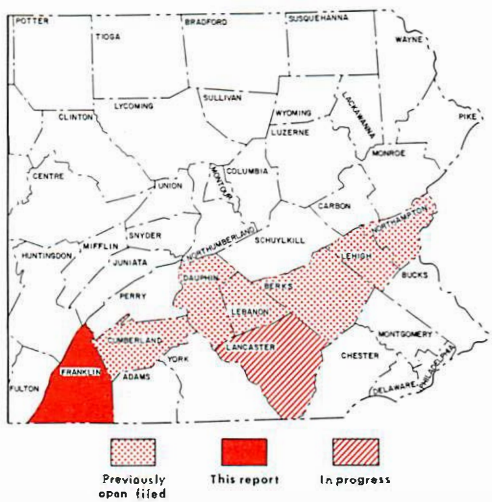
Warren County in northwestern Pennsylvania remains the most active county for oil well drilling. The most active counties for gas well drilling include Venango, Erie, Crawford, Indiana, Warren, Armstrong, and Clearfield.

Progress Report 202, **Oil and Gas Developments in Pennsylvania in 1988**, is available for $3.25, plus $0.20 sales tax for Pennsylvania residents, from the State Book Store, P.O. Box 1365, Harrisburg, PA 17105. Orders must be prepaid; please make checks payable to *Commonwealth of Pennsylvania*.

—P. F. Buis

OPEN-FILE REPORT ON SINKHOLES OF FRANKLIN COUNTY

The Pennsylvania Geological Survey announces the release of Open-File Report 89-03, **Sinkholes and Karst-Related Features of Franklin County, Pennsylvania**, by staff geologist William E. Kochanov. This report is part of a series designed to indicate areas of known sinkhole occurrence and potential sinkhole development. Environmental problems associated with sinkhole subsidence in the carbonate rocks of central and southeastern Pennsylvania have dramatized the need for greater understanding and information about weathering processes in carbonate bedrock and how these processes can affect bedrock stability in building and construction areas.



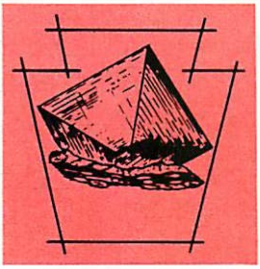
The report consists of nineteen 7.5-minute topographic maps (scale 1:24,000) and a brief text. The maps depict known sinkhole occurrences, carbonate geology, past and present surface mine locations, caves, and other karst-related features having surface expression. Similar reports have been prepared for Northampton, Lehigh, Berks, Lebanon, Dauphin, and Cumberland Counties.

In conjunction with the maps, a comprehensive computer data base is being developed at the Survey to store available sinkhole data (locations, physical characteristics, and methods of repair). The compilation of these data will provide a quick and useful source of additional background information for planning and land development in areas of carbonate bedrock.

Open-File Report 89-03 should be of considerable interest to county and municipal planning groups, engineers, state and federal agencies, and residents of Franklin County.

The Franklin County open-file report may be examined at the Survey's offices on the 9th floor of the Executive House, 101 South Second Street, Harrisburg, or copies of the report may be purchased by mail at the prepaid copying and shipping cost of $47.50 from the Bureau of Topographic and Geologic Survey, Department of Environmental Resources, P.O. Box 2357, Harrisburg, PA 17105. Pennsylvania residents should include $2.85 sales tax. Please make checks payable to *Commonwealth of Pennsylvania*.

—*W. E. Kochanov*



EARTH SCIENCE TEACHERS' CORNER

AGI "Connection"

The American Geological Institute (AGI) has issued a new communication service for earth science teachers. Prepared by the National Center for Earth Science Education of AGI, it is called *Earth Science Education Connection*. The object of *Connection* is to "foster advocates for Earth science education, and provide a forum for scientists and educators to exchange ideas and information that affect it." *Connection* will be published quarterly (volume 1, number 1 was issued as the Summer 1989 edition) and will be distributed free of charge. To receive the newsletter, write to the editor, Mark T. Schmidt, American Geological Institute, 4220 King Street, Alexandria, VA 22302-9990.

Resources for Earth Science Teachers–1989

AGI has also issued a four-page compilation of earth science references and enrichment materials, including catalogs, publication lists, teachers' packets, books, and journals. Write to AGI at the above address for a copy of this listing.

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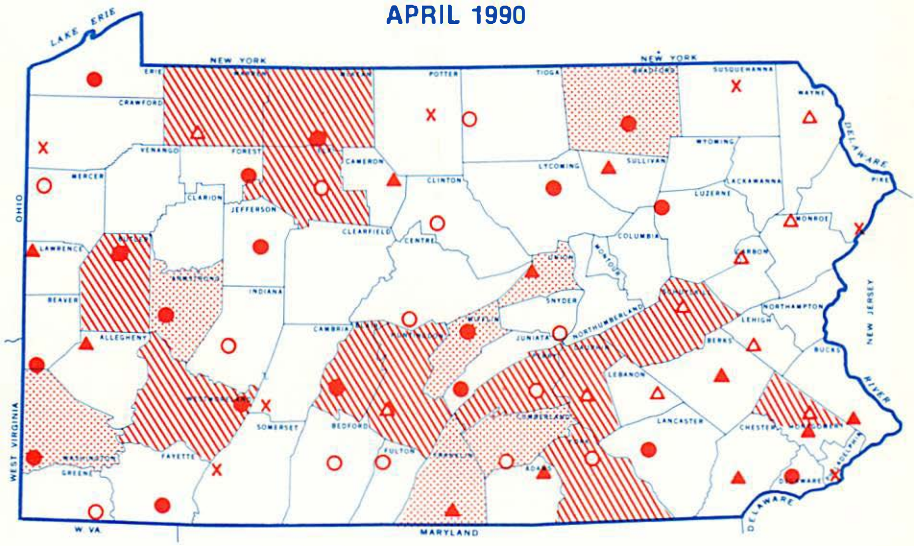
TOPOGRAPHIC MAPPING
GROUNDWATER-RESOURCE MAPPING

GROUNDWATER LEVELS FOR APRIL 1990



EXPLANATION

Observation well		Observation well equipped with data-collection platform					
○ Above last year	● Below last year	△ Above last year	▲ Below last year	x No data	High	Normal range	Low

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Bureau of Topographic and Geologic Survey
Department of Environmental Resources
P. O. Box 2357
Harrisburg, PA 17105

Address Corrections Requested

DER #103-6/90