VOL. 32, NO. 1

Pennsylvania GEOLOGY

COMMONWEALTH OF PENNSYLVANIA
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CONTENTS

ON THE COVER

New headquarters for the Bureau of Topographic and Geologic Survey in Middletown, Pa. (see article on p. 12). The view is of the front of the building, looking across Dogwood Lane. The main entrance is left of the flagpole, and there is a separate entrance to the library, which is on the right beyond the view of the photograph. Photograph by Gary M. Fleeger.

PENNSYLVANIA GEOLOGY

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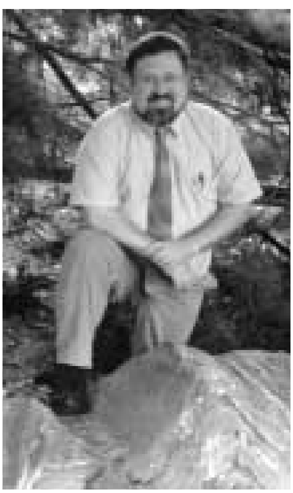
VOL. 32, NO. 1 **SPRING 2002**

Greetings From Your State Geologist

When I was about 10 years old, I started receiving *Pennsylvania Geology,* and I would eagerly read it, hoping to glean some new insight into rocks. Even when I had no idea what an article was about, I felt like I was a part of the greater scientific community, because I knew that somewhere there were real geologists doing cool geologic things and reporting back to me.

I never had any intention of being a state geologist. I am, by training, a geophysicist who has a special interest in geobotanical remote sensing. I have worked for Mobil Oil, done research at NASA's Jet Propulsion Lab, and been a college professor, an environmental consultant, and most recently, the director of GIS for Lancaster County. As a result, I'm not a great field geologist, but I do bring wide experience in a variety of areas that the Survey is poised to pursue, for example, GIS, education, remote sensing, geophysics, electronic data collection and publication, and web mapping. Field mapping will remain the core of what the Survey does, and we will publish the results of our work to make it accessible. My goal is for the Survey to meet your needs, from geologic consultants to the 10-year-old child yearning for tales of the geologic safari.



On a personal note, Sam Berkheiser did an excellent job as interim state geologist. He continues to be a great help, and I am grateful for that help in this period of transition. And . . . we've moved! Our new office (see the article on p. 12) is a very user-friendly building with plenty of parking. Please stop by and visit us at our open house on April 10, or anytime.

And, just so you know, as a kid, I never bothered reading the editorial.

Jay Parrish

Jay B. Parrish
State Geologist

Lake Monongahela: Anatomy of an Immense Ice Age Pond

by John A. Harper
Bureau of Topographic and Geologic Survey

IN THE BEGINNING . . . Several years ago, an article appeared in this magazine describing how glaciers reversed the direction of drainage in western Pennsylvania during the Ice Age, forcing the originally northwest-flowing streams to flow southwestward around the front of the advancing ice sheets (Harper, 1997). Prior to the Ice Age, the Allegheny River consisted of three separate and unrelated rivers that drained different parts of the state. The “Upper Allegheny” River began in north-central Pennsylvania and flowed across New York into Canada. The “Middle Allegheny” River started in Warren County and, after wending its way through northern Venango County, flowed northwest along what is now the valley of French Creek into Canada. The “Lower Allegheny” River originated in Elk, Forest, and Jefferson Counties, followed the course of the present-day Clarion River, and eventually flowed south to join the Monongahela River at what is now Pittsburgh. The preglacial Ohio River was a mere tributary of the Monongahela River, the dominant river in western Pennsylvania. The Monongahela flowed north out of West Virginia to Pittsburgh, and then followed the present Ohio and Beaver River channels northwestward through Ohio and into Canada. The preglacial Monongahela River system drained about three fourths of the area presently drained by the combined Ohio, Monongahela, and Allegheny Rivers and their tributaries in Pennsylvania.

When the Ice Age began in Pennsylvania some 900,000 years ago (Figure 1), the advancing ice sheets blocked the northwest-flowing streams, creating ponds and lakes of varying extents within the existing drainage areas. As the ponded waters rose, they eventually crested and eroded notches in their drainage divides. The escaping waters scoured the landscape and formed new drainage channels that flowed southwestward, closely paralleling the front of the glaciers. The three Allegheny Rivers coalesced to form one, and the mighty Monongahela was forced to flow up the valley of its minor tributary, the Ohio. The Ohio became the major stream of western Pennsylvania, flowing south and then west along the boundary of the ice to the Mississippi River.

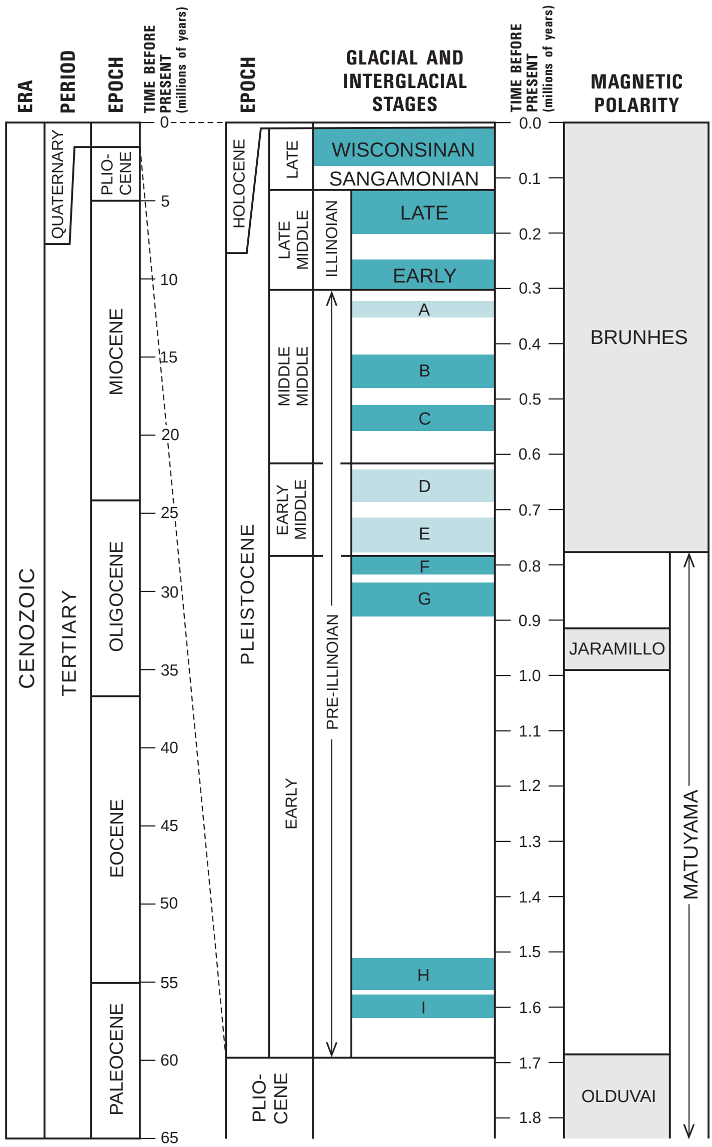


Figure 1. Glacial (teal) and interglacial stages of the Pleistocene Epoch correlated with reversals of the earth's magnetic field (normal polarity is shown in gray). Glacial episodes known or inferred to have occurred in Pennsylvania are shown in the darker shade of teal (based on Braun, 1988).

Ponding occurred each time a glacial advance blocked the rivers, but there is some disagreement as to how many such episodes occurred in western Pennsylvania. The ponds that formed during each succeeding glacial advance never reached the level of the previous ponding. The notches in the drainage divides, however, continued to be deepened each time a pond or lake formed and the water found an outlet, and the river channels became entrenched (Marine, 1997).

LAKE MONONGAHELA. The Monongahela River was the major stream before and during much of the Ice Age, draining a large area of Pennsylvania and West Virginia. (It was so different that some geologists refer to its Ice Age "persona" as the Pittsburgh River to distinguish it from the river we now know.) When the glaciers dammed the river and the waters backed up, the lake that formed was enormous (Figure 2). I. C. White, the first director of the West Virginia Geological Survey, named this body of water Lake Monongahela (White, 1896). It was not a "lake" in the normal sense of the word (like Lake Erie), but rather a ponded drainage system similar to man-made lakes (like Raystown Lake in central Pennsylvania or Deep Creek Lake in western Maryland), only on a much larger scale. Figure 2 also indicates that the lake extended an unknown distance along the Ohio and Allegheny drainages beyond what is shown.

Most of what we know or can speculate about Lake Monongahela comes from studies of terrace deposits found at high elevations along or near the present river channels in West Virginia, Pennsylvania, and Ohio. The Monongahela River system became impounded at least twice, forming a new Lake Monongahela each time, and each succeeding lake left evidence at a different elevation (White, 1896; Leverett, 1934).

TERRACE ANYONE? White (1896) and Marine (1997) described a series of five erosional terraces that occur along or near the valley walls of the Ohio, Monongahela, and Allegheny Rivers and their major tributaries in Pennsylvania and West Virginia (Table 1) (Lessig, 1961, recognized only four in Ohio). These relatively flat landforms contain soils composed of highly weathered deposits of clay, silt, sand, and gravel distributed at elevations as high as 300 feet or more above present stream levels. Many of these sediments are characteristic of lacustrine, or lake-derived, deposition.

The terrace deposits found at high elevations are scattered throughout southwestern Pennsylvania (for example, Figure 3 shows their distribution in Allegheny County). These deposits comprise two, and possibly more, separate formations of Pleistocene age: the Carmichaels Formation and glacial outwash deposits.

Campbell (1902) named the Carmichaels Formation for lacustrine sediments exposed at Carmichaels in Greene County, Pa. Carmichaels Formation terrace deposits occur throughout southwestern

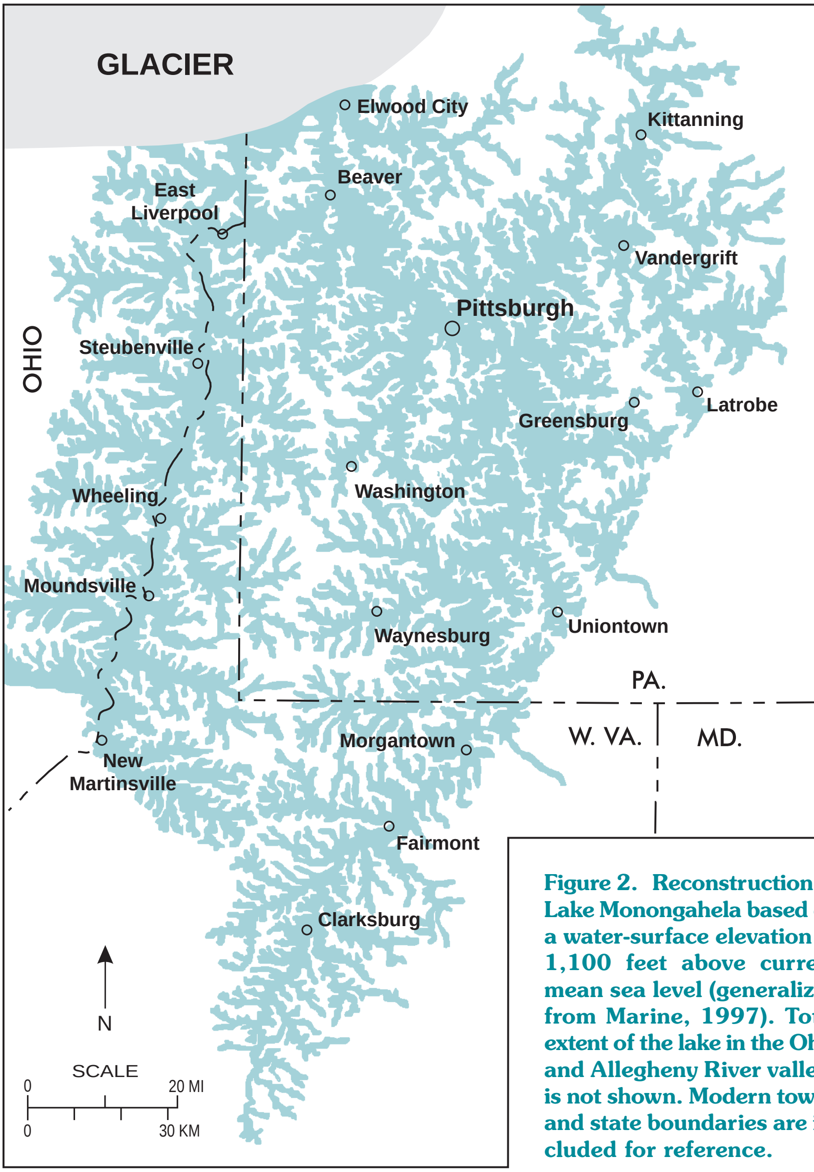


Figure 2. Reconstruction of Lake Monongahela based on a water-surface elevation of 1,100 feet above current mean sea level (generalized from Marine, 1997). Total extent of the lake in the Ohio and Allegheny River valleys is not shown. Modern towns and state boundaries are included for reference.

Pennsylvania and northern West Virginia. These sediments typically consist of reddish-orange to tan clays, silts, and sands that often contain cobbles and boulders derived from the local bedrock (Donahue and Kirchner, 1998) (Figure 4A). The clays commonly are of high quality and were the source of raw materials for the early pottery industry in the greater Pittsburgh area. Carmichaels Formation deposits

Table 1. *Levels of Terraces Above the Three Rivers in the Pittsburgh Area*
(from Marine, 1997)

Terrace	Distance above river level (feet)[1]	Distance above mean sea level (feet)
First	30	740
Second	160	900
Third	220	960
Fourth	260	1,000
Fifth	330	1,040

[1]Normal pool level.

occur on the upper two terrace levels in all the river valleys, but they can also be found draped over lower terraces in the Monongahela Valley and the valleys of the eastern tributaries of the Allegheny River.

The glacial outwash deposits found on the Allegheny, Ohio, and Beaver River terraces have no formal names. These deposits typically are rust-colored, deeply weathered gravels composed of small, well-rounded pebbles generally less than 1 inch in diameter (Figure 4B). About 10 percent of the pebbles are granites and other crystalline rocks. Some of these deposits have been thoroughly cemented to form sandstones and conglomerates, whereas others are loose assortments of silt, sand, and gravel. These outwash deposits occur on several terrace levels. Given the time and expertise of an enterprising field geologist or graduate student, it is likely these outwash deposits could be separated and correlated with the known glaciations of northwestern Pennsylvania described by White and others (1969).

Terrace deposits can be quite thick. Some preserved outwash deposits have been measured at more than 90 feet thick, and Leverett (1934) estimated that thicknesses might originally have exceeded 120 feet. Carmichaels deposits tend to be much thinner, rarely exceeding 20 feet. Hickock (Hickock and Moyer, 1940), however, indicated that these deposits were as much as 80 feet thick in Fayette County.

The five individual terraces do not maintain constant elevations throughout western Pennsylvania. For example, the second terrace along the Allegheny River typically is more than 900 feet above sea level (Marine, 1997), whereas the same terrace level along the Monongahela lies about 25 or 30 feet lower (White, 1896). The gradient of the Allegheny, at about 3 feet per mile, also is much steeper than the approximately 0.8-foot-per-mile gradient of the Monongahela. These conditions probably resulted from eustatic adjustment of the earth's crust (crustal rebound) north of Pittsburgh following the retreat of the approximately 2-mile-thick Wisconsinan glacier about 10,000 years ago.

The highest (fifth) terrace occurs more than 300 feet above the current stream levels (Table 1) and can exceed 1,100 feet above sea

Figure 3. Locations of remnant terrace deposits in Allegheny County (compiled from Wagner and others, 1975). The modern floodplain (first terrace) is not included.

level north of Pittsburgh. Remnants of this terrace actually are higher than the glacial outwash deposits in the Allegheny River valley. They represent the channels of streams flowing through western Pennsylvania before the Ice Age. The Carmichaels Formation deposits covering those terrace remnants probably represent the highest level reached by Lake Monongahela during the latest early Pleistocene glaciation (F and/or G in Figure 1) (White, 1896; Leverett, 1934; Marine, 1997).

By the time of the late Illinoian glacial advance (and probably much earlier than that), large amounts of glacial outwash were transported down the joined Allegheny Rivers and deposited along the valley walls. Therefore, most of the fourth, third, and second terrace levels on the Ohio and Allegheny Rivers contain deposits composed

A

B

Figure 4. Photographs of Pleistocene terrace deposits in southwestern Pennsylvania. Rock hammers for scale. A. Sandstone cobbles and boulders in red sand, silt, and clay characterize the Carmichaels Formation at Speers, Washington County. B. Glacial outwash deposits of sand and gravel found along the Allegheny, Ohio, and Beaver River drainages, such as this one in O'Hara Township, Allegheny County (Wagner and others, 1970), have never been named.

mainly of outwash sand and gravel. Terraces occurring at the same elevations along the Monongahela River and the eastern tributaries of the Allegheny River tend to have deposits consisting of varying amounts of sand, silt, and clay, and occasional boulders of local origin (Carmichaels or Carmichaels-type deposits).

The first terrace lies at an elevation of 740 feet above sea level in downtown Pittsburgh. It climbs in elevation to about 930 feet in the farthest reaches of the Allegheny River and about 830 feet on the upper Monongahela River while maintaining a distance above river level of 30 to 40 feet. This is the modern floodplain, which is composed primarily of Wisconsinan glacial outwash in the Allegheny and Ohio Valleys, and sand, silt, and mud containing locally derived cobbles and boulders in the Monongahela Valley. These deposits have been capped by and mixed with river sediments (alluvium) less than 10,000 years old.

The process of creating terraces will continue as long as the rivers flow. As the streams continue to cut down their channels and lower their gradients, and/or as the land continues to rise in response to crustal rebound, remnants of the current floodplain will be preserved as future terrace remnants.

FROM AGE TO AGE. The ages of the various terrace deposits have been debated for more than a century. Early workers such as White (1896) and Leverett (1934) studied the degree of weathering in granite pebbles and the development of soil profiles within the terrace deposits. These methods suggested a pre-Illinoian age for the higher terraces. Modern radiocarbon dating of organic debris in a high terrace deposit near Morgantown, W. Va., suggests a Wisconsinan age of approximately 22,000 years before present (Gillespie and Clendening, 1968; Behling and Kite, 1988).

The question is further complicated by recent paleomagnetic data. Clay particles formed from weathered rocks containing magnetic iron minerals (such as hematite) can be small enough to become aligned with the earth's magnetic field. As such, they can indicate the direction and intensity of the field at the time of deposition or consolidation of the sediment, thereby retaining the "memory" of the magnetic field. Jacobson and others (1988) and Bonnett and others (1991) obtained reversed magnetic polarity data from third terrace clays in West Virginia and Ohio, indicating a reversal of the earth's magnetic field during the time of deposition. The most recent paleomagnetic reversal, the Matuyama, ended 788,000 years ago (Figure 1), suggesting the higher (third through fifth) terrace deposits formed before this time. Marine (1997) also found a reversed magnetic polarity signature from a single sample collected from the fourth terrace in Armstrong County, Pa. However, he concluded that its value was suspect because none of the other samples from the same horizon, nor from any of the other horizons at various levels and localities in the lower Allegheny drainage, exhibited anything but normal polarity.

The data obtained by radiocarbon dating and paleomagnetic analysis are not particularly compelling. Leaching of the sediments containing organic remains might be enough to discount the few observed radiocarbon dates. Besides, 22,000 years approaches the limits of reliability of the radiocarbon dating technology. The paleomagnetic results are equally suspect. Marine (1997) sampled many deposits from many terraces in the lower Allegheny drainage, but he obtained a reversed polarity reading from only one sample. This suggests that the paleomagnetic reversals documented in West Virginia and Ohio need to be further verified, and that a larger paleomagnetic database needs to be compiled to better constrain the age of the high terrace deposits associated with Lake Monongahela.

SO—WHAT'S REALLY GOING ON HERE? Is there a good explanation for the various contrary information associated with Lake Monongahela terrace deposits? How many terraces were there, really, and how many episodes of ponding? When did they occur?

First of all, Lake Monongahela did not actually create the terraces. In most cases, Carmichaels Formation sediments sit directly on bedrock, indicating that the lake merely deposited sediment on preexisting terraces. Considering that it would have taken only a few years for the ponded lake waters to rise to a high enough level to crest and erode through the existing drainage divides, Lake Monongahela would not have had sufficient time to cut terraces in the local bedrock during any of the ponding episodes.

It was the rivers and their tributaries that created the terraces during separate depositional and erosional episodes before, during, and after the Ice Age. The major rivers of western Pennsylvania existed millions of years before the Ice Age. They were mature streams that modified their channels as they meandered within relatively broad valleys. During the Ice Age, these streams cut their way downward, abandoning meanders and leaving everything from complete loops to fragments of meanders preserved as terrace remnants lining the river valleys. Some meanders were far enough inland from the eroding channels to be preserved as uncharacteristically flat swaths of land within western Pennsylvania's normally hilly topography. They can be seen at places like Carmichaels in Greene County (Monongahela River cutoff meander), Perryopolis in Fayette County (Youghiogheny

River cutoff meander), and Perrysville, across from Parker, in Armstrong County (Allegheny River cutoff meander), to name just a few.

Once Lake Monongahela formed, the ponded waters drowned the topography, including the abandoned meanders and terraces. The lake did not erode the topography—it simply covered the land with water and lacustrine sediment. The sediment settled on both topographic highs and lows beneath the surface of the lake. Drowned terraces and abandoned meander channels, as well as low hills, slopes, and valley bottoms, received this covering of sediment. As such, sediments found on different terraces can actually be the same age.

Marine (1997) found five terrace levels along the rivers, but he had to conclude that the lake deposits found on them resulted from only two episodes of glacial damming. Deposits on the fifth and fourth terrace levels represent damming during a pre-Illinoian glaciation, whereas the third- and second-terrace-level deposits represent damming during Illinoian glaciation. The first terrace (the modern floodplain) consists simply of Wisconsinan outwash and Holocene alluvial deposits, which fill river valleys that had been cut to bedrock by the end of Illinoian time. It does not represent a ponding episode.

It will take another Ice Age to recreate Lake Monongahela (this is not as far-fetched as it sounds). Of course, when that happens, we will have to call it Lake Ohio. Depending on the southern extent of the glacial ice dam, the lake might extend from as far away as Illinois to West Virginia and New York. Then we will have a truly Great Lake.

REFERENCES

Behling, R. E., and Kite, J. S., 1988, Additional radiocarbon dates on the late Quaternary history of the Monongahela River basin, West Virginia [abs.]: Geological Society of America Abstracts with Programs, v. 20, p. 334.

Bonnett, R. B., Noltimier, H. C., and Sanderson, D. D., 1991, A paleomagnetic study of the early Pleistocene Minford Silt Member, Teays Formation, West Virginia: Geological Society of America Special Paper 258, p. 9–18.

Braun, D. D., 1988, Glacial geology of the Anthracite and North Branch Susquehanna lowland regions, *in* Inners, J. D., ed., Bedrock and glacial geology of the North Branch Susquehanna lowland and the Eastern Middle Anthracite field, northeastern Pennsylvania: Annual Field Conference of Pennsylvania Geologists, 53rd, Hazleton, Pa., Guidebook, p. 3–25.

Campbell, M. R., 1902, Masontown-Uniontown folio, Pennsylvania: U.S. Geological Survey Geologic Atlas of the U.S., Folio 82, 21 p.

Donahue, Jack, and Kirchner, Brian, 1998, Pleistocene Lake Monongahela and the Carmichaels Formation in southwest Pennsylvania: Pittsburgh Geological Society, Spring Field Trip Guidebook [not paged].

Gillespie, W. H., and Clendening, J. A., 1968, A flora from proglacial Lake Monongahela: Castanea, v. 33, p. 267–300.

Harper, J. A., 1997, Of ice and waters flowing—the formation of Pittsburgh's three rivers: Pennsylvania Geology, v. 28, no. 3/4, p. 2–8.

Hickock, W. O., IV, and Moyer, F. T., 1940, Geology and mineral resources of Fayette County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., County Report 26, 530 p.

Jacobson, R. B., Elston, D. P., and Heaton, J. W., 1988, Stratigraphy and magnetic polarity of the high terrace remnants in the upper Ohio and Monongahela Rivers in West Virginia, Pennsylvania, and Ohio: Quaternary Research, v. 29, p. 216–232.

Lessig, H. D., 1961, Soils of the high terrace remnants in the upper Ohio Valley: Ohio Journal of Science, v. 61, p. 286–294.

Leverett, Frank, 1934, Glacial deposits outside the Wisconsin terminal moraine in Pennsylvania: Pennsylvania Geological Survey, 4th ser., General Geology Report 7, 123 p.

Marine, J. T., 1997, Terrace deposits associated with ancient Lake Monongahela in the lower Allegheny drainage, western Pennsylvania: University of Pittsburgh, M.S. thesis, 182 p.

Wagner, W. R., Craft, J. L., Heyman, Louis, and Harper, J. A., comps., 1975, Greater Pittsburgh region geologic map and cross sections: Pennsylvania Geological Survey, 4th ser., Map 42, scale 1:250,000, 4 sheets.

Wagner, W. R., Heyman, Louis, Gray, R. E., and others, 1970, Geology of the Pittsburgh area: Pennsylvania Geological Survey, 4th ser., General Geology Report 59, p. 90.

White, G. W., Totten, S. M., and Gross, D. L., 1969, Pleistocene stratigraphy of northwestern Pennsylvania: Pennsylvania Geological Survey, 4th ser., General Geology Report 55, 88 p.

White, I. C., 1896, Origin of the high terrace deposits of the Monongahela River: American Geologist, v. 18, p. 368–379.

ANNOUNCEMENT

Survey Gets New Digs and Hosts Open House

In January 2002, the Bureau of Topographic and Geologic Survey moved out of its Harrisburg headquarters and into the R. E. Wright building (front cover) in Middletown, Pa. Our new mailing address and telephone numbers are listed on the inside back cover.

The Survey's new office is located approximately 12 miles southeast of Harrisburg, off the Hummelstown-Middletown exit of Route 283, which is easily accessible from the Pennsylvania Turnpike (exit 19) or Inter-

Superstrong Survey Senior Geologic Scientist, Bill Kochanov, lifts a stack of boxes filled with heavy rocks!

At the main entrance of the building is a reception area where visitors are welcomed by Survey staff. Here, Jody Zipperer greets John Diehl of the Department of Environmental Protection.

state 83 (see the back cover for maps and driving instructions).

The Survey offices and library are on the upper level of the building, and laboratory and storage facilities occupy part of the lower level. There are plans to convert a large room on the lower level to an activity center where young visitors and their older companions can have fun learning about Pennsylvania's geology.

The upper level of the building also houses a large conference room (the Learning Center), a computer lab, and a water-well records area. The conference and computer rooms are used for meetings and training classes by Bureau and Department personnel. Anyone wishing to present geologic or related research to Survey staff at our weekly seminar series may use the Learning Center and should contact Kristen Reinersten at 717–702–2047 to make arrangements. The water-well records area contains water-well completion reports for approximately the last 15 years. Consultants and other visitors who wish to view or photocopy drillers' records on well locations, depths, yields, water-bearing zones, and rock types encountered should contact Jody Zipperer at 717–702–2073 to arrange an appointment.

The Survey will be holding an **open house** on Wednesday, April 10. Project work will be on display, and there will be goodies of both edible and printed varieties. Please come and visit us at our Middletown office. Open house hours will be from 10 a.m. to 3 p.m.

The Survey's library has a large collection of topographic maps, aerial photographs, and geologic texts, maps, and journals. With the exception of the topographic maps, most materials are circulated. Here, patron Tom Warman and librarian Rick Keen (background) are hard at work.

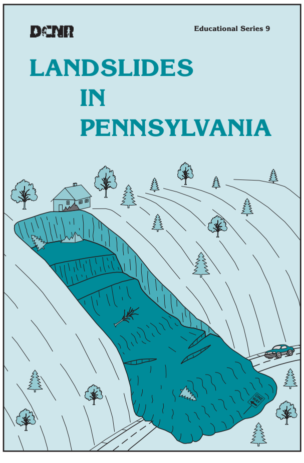
EARTH SCIENCE TEACHERS' CORNER

Survey's Educational Series Now Includes Landslides and Nonfuel Mineral Resources

The Bureau of Topographic and Geologic Survey publishes a series of free booklets designed to educate students and the public about geology in Pennsylvania. There are now 12 booklets in the Educational Series (ES); each addresses a specific geologic topic (for example, groundwater or fossils) and is written at a level easily read by high-school students. The booklets have been a valuable aid to teachers, who can supplement their instructions with free handouts or use them as a source of information.

At 6 by 9 inches and 14 to 44 pages in length, these booklets are a convenient size and well illustrated with photographs and sketches. Most of them are displayed on the Survey's web site at www.dcnr.state.pa.us/topogeo/pub/pub.htm. For a complete list of the ES series, see the Survey's *List of Publications*, which is also available on the web site. The booklets are free upon request and may be ordered through the web site or from the Bureau of Topographic and Geologic Survey, 3240 Schoolhouse Road, Middletown, PA 17057–3534, telephone 717–702–2017.

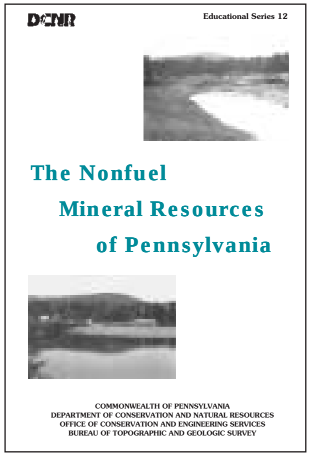
There are two recent additions to the Survey's Educational Series. **ES 9, Landslides in Pennsylvania,** written by staff geologist Helen L. Delano, is a new 34-page edition of what was formerly titled *Geologic Hazards in Pennsylvania*. The old edition included sections on landslides, sinkholes (now in ES 11) and earthquakes (ES 10). Landslides (along with floods and sinkholes) are among the major geologic hazards affecting the state. Although total numbers of occurrences and associated costs of landslides are unknown, costs probably average several tens of millions of dollars per year in Pennsylvania. Roads,



utilities, and buildings can be damaged by landslides, but travel delays, interruption of businesses and utility services, and other side effects also contribute to the costs. Although landslides are a natural phenomenon, people occupying and modifying the land surface trigger many, if not most, slope failures in Pennsylvania.

ES 9 includes descriptions of the types of landslides common in Pennsylvania and where they may occur. It has generalized maps of landslide distribution in the state and references to more detailed information. Landslide occurrences can be greatly reduced by avoiding construction in some areas and modifying construction practices in others. The first step is understanding how and where landslides occur. It is hoped that the revised ES 9 will increase awareness and understanding of this hazard.

ES 12, The Nonfuel Mineral Resources of Pennsylvania, by staff geologists John H. Barnes and Robert C. Smith, II, is a new booklet on mineral resources other than coal, oil, and natural gas. From the earliest days of William Penn's "holy experiment," when the colonists were advised to build houses of brick to reduce the danger of fire, to the present time, when they constitute a billion-dollar-per-year industry in Pennsylvania, mineral resources have helped to shape the development of the Commonwealth.



In the first part of this 38-page booklet, the authors discuss the nonfuel mineral resources that are presently mined in Pennsylvania and how they are used in many everyday activities. The second part of the booklet is an exploration of the interesting role that mineral resources played in shaping Pennsylvania's history. Mining in Pennsylvania began at least 15,000 years ago with the excavation of rocks that native Americans used to make tools. Later, Pennsylvania became an important center for the mining of materials that helped to build our nation's manufacturing industries. It was an important source of chromium, iron, nickel, lead, and zinc. Pennsylvania has also been a limited source of gold, silver, copper, manganese, salt, feldspar, and other commodities. The booklet ends with a look toward the future and a discussion of the role of mining in modern society.

Reports on Coal-Bed Methane Resources

Two reports by staff geologist Antonette K. Markowski on coal-bed methane (CBM) resources have been published by the Bureau of Topographic and Geologic Survey. **Mineral Resource Report 95, Reconnaissance of the Coal-Bed Methane Resources in Pennsylvania,** will interest the natural gas industry and those who wish to make the coal industry safer and more lucrative by capturing and marketing a dangerous and previously overlooked resource. In this 134-page report, the author describes the history, geology, production, and economic potential of CBM in Pennsylvania.

Estimates of CBM indicate that there may be 51 trillion cubic feet of gas-in-place in Pennsylvania and West Virginia.

CBM has heating values comparable to conventional natural gas. In 2000, there were approximately 125 wells producing commercial methane gas and many others that had been drilled for exploration and testing purposes in the Commonwealth. CBM can be produced from coal seams that are too thin or deep to permit economic mining, and its production has less environmental impact than conventional gas drilling.

Mineral Resource Report 95 may be purchased from the State Bookstore, Commonwealth Keystone Building, 400 North Street, Harrisburg, PA 17120–0053, telephone 717–787–5109, for **$10.00 plus $0.60 sales tax** for Pennsylvania residents. Payment may be made with VISA, MasterCard, or check or money order payable to *Commonwealth of Pennsylvania*. If order is to be mailed, include **$4.00 postage** for one book and **$0.50** for each additional book.

The second CBM report is a 580-page spreadsheet available as a Microsoft® Excel 97 file on a 3.5-inch diskette. **Open-File Report 00–01, Pennsylvania Coal-Bed Methane Wells,** includes data from exploratory and producing CBM wells and from serendipitous encounters with the gas in the state from 1938 to 2000.

Open-File Report 00–01 may be purchased for **$2.00 plus $0.12 state sales tax**. Prepayment is required; please make check or money order payable to *Commonwealth of Pennsylvania* and send to Open-File Sales at the Survey's Middletown address (see inside back cover). If interested in additional CBM information, contact Toni Markowski at 717–702–2038.

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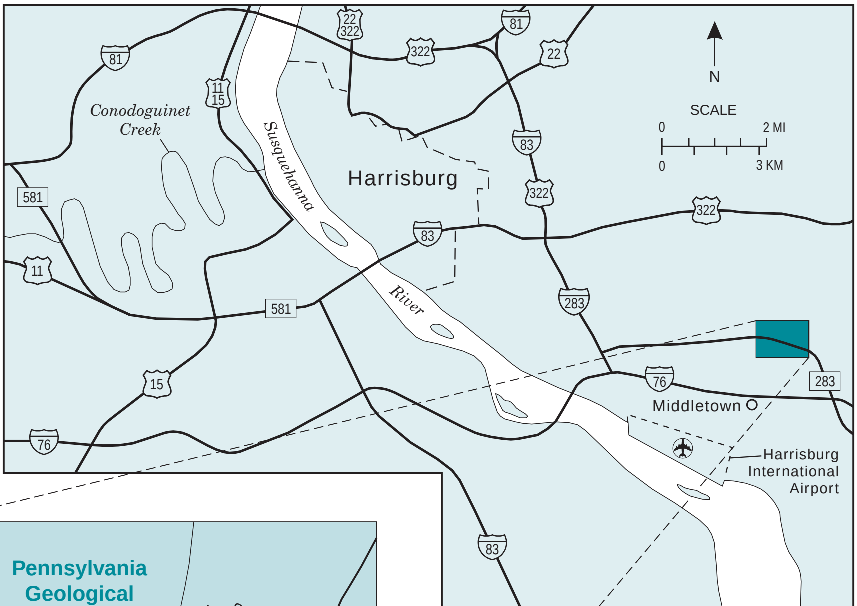
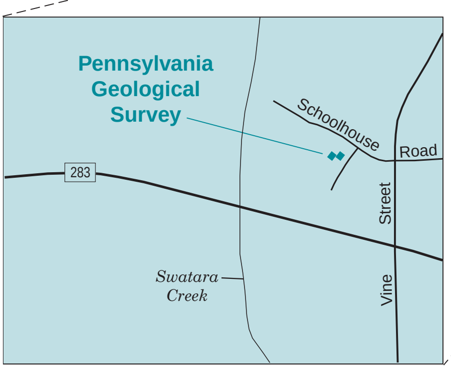
IN COOPERATION WITH THE U.S. GEOLOGICAL SURVEY
TOPOGRAPHIC MAPPING
GROUNDWATER-RESOURCE MAPPING

LOCATION MAP FOR BUREAU'S NEW HEADQUARTERS





Directions

From Harrisburg—Follow I-83 North to I-283 South. Take the Lancaster exit onto Route 283 East.

From the PA Turnpike—Take exit 19, Harrisburg East, and then take the first exit onto Route 283 East.

From Route 283 East—Take the Hummelstown-Middletown exit. At the end of the ramp, turn left onto Vine Street. Stay in the left-hand lane and turn left at the first intersection onto Schoolhouse Road. Make the next left onto Dogwood Lane. At the top of the hill, take the first right into the parking lot.

Bureau of Topographic and Geologic Survey
Department of Conservation and Natural Resources
3240 Schoolhouse Road
Middletown, PA 17057–3534

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