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Flooding in Middletown, Pa. This photograph was taken at 11:30 a.m. on Saturday, March 12, 2011, along South Union Street in Middletown. Floodwaters are sweeping across the parking lot of the boat dock, which is located in the break of the trees (middle right) in the photograph. The boat dock is on Swatara Creek, just east of the confluence of Swatara Creek and the Susquehanna River. Only two hours prior, the flood crested at 16.4 feet at the stream gage located upstream at the Grubb Street bridge near Hoffer Park in Middletown. Flood stage is at 11 feet for this gage. See article on page 3.

—Photograph by Stuart O. Reese

EDITORIAL

First Words from the Latest State Geologist

George E. W. Love, State Geologist
Pennsylvania Geological Survey

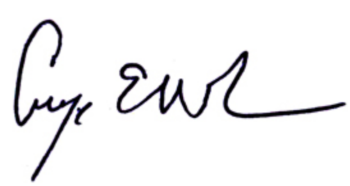
As Stuart Reese, the bureau's supervisor of the Groundwater and Environmental Geology Section, points out, Pennsylvania is fortunate to have an abundance of water, sometimes! In this issue of *Pennsylvania Geology*, he discusses the hydrologic cycle—what it is, how it "operates," and what we as individuals can do to impact that cycle in a positive way. Stuart's thoughtful explanation occurs at a time when Pennsylvanians are concerned about the use of water resources by the Marcellus drillers, and about the flooding due to recent heavy and extended rainfall. To be sure, we should not underestimate the value of this resource, or the power it wields in shaping our lives, our landscape, and our long-term well-being.

Coupled with this article is Duane Braun's description of Pennsylvania's glacial history and a new glacial map resource. What an interesting twist on water and its impacts on the landscape, albeit from a slightly different perspective! The features we see along the northern tier of our commonwealth, those that have resulted from episodic, and sometimes apocalyptic, incursions of water (as ice), help to remind us of the ever-changing nature of our world.

In a third article, John Barnes brings us news of the instrumental additions to our laboratory. Geology, which some people feel is a "done deal" once the maps are made, is constantly changing as more facts are revealed. Our thoughts change as careful analyses show new bits of data that allow new, better, or perhaps just more interesting interpretations. It never ceases to amaze me that we can glean millions of years of geologic history from the fission tracks, chemical components, or daughter products contained within a single crystal!

I hope you will enjoy these articles and learn something from the authors to share with your friends and family. The Pennsylvania Geological Survey is a resource for all Pennsylvanians and anyone anywhere who enjoys the opportunity to learn.

Finally, I must say something of a personal nature. This is my first editorial as the Pennsylvania State Geologist. Frankly, the task is daunting, not that the subject is hard, not that words are difficult to come by, but because the shoes are hard to fill. I have been fortunate in my career to have met three Pennsylvania State Geologists and have been even more fortunate to know personally the two most recent holders of this position. Additionally, it has been a privilege to have worked for and with Dr. Jay Parrish, my predecessor, my mentor, and most sincerely, my friend.



Rethinking the Hydrologic Cycle

Stuart O. Reese
Pennsylvania Geological Survey

Ride the Cycle

Water, in one form or another, is all around us. Every living thing ultimately depends on water. The "hydrologic cycle" (or water cycle) is the term for the continuous movement of water from one place and phase to another. Examples of water-cycle processes are shown in Figure 1.

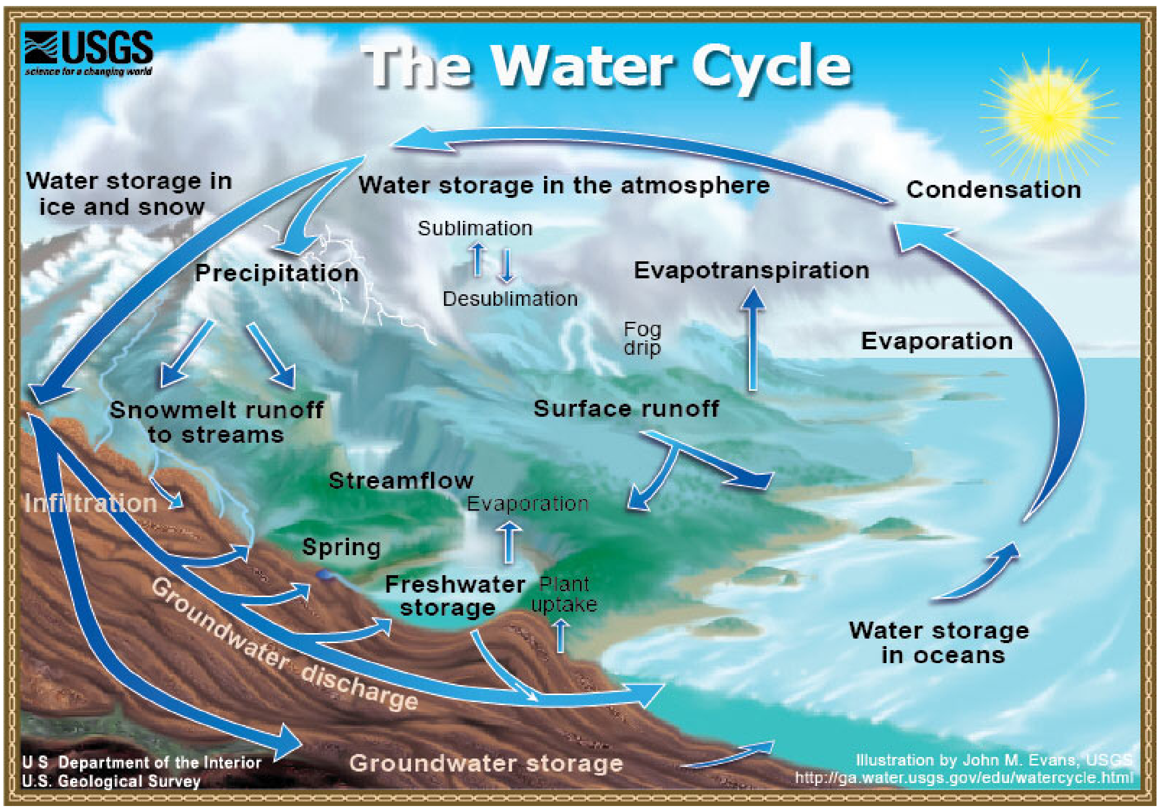


Figure 1. The water cycle (U.S. Geological Survey, 2011).

"When it Rains…"

With its many intricate paths and parts, the water cycle is very complex. Hydrologists like to simplify matters by accounting for water in a budget. And like a financial budget, a water budget starts with income (precipitation). From there it takes the following multiple paths:

- evaporation sends water back into the air;
- precipitation coats the land's surface, where thirsty plants intercept it and then transpire some of it back into the atmosphere;
- runoff water is collected in trickling seeps and rivulets and sent to streams, rivers, lakes, and oceans;

- water infiltrates the surface to become groundwater, which flows much more slowly and typically heads for nearby streams (discharge points);
- in Pennsylvania, precipitation gets hung up as ice in the winter months;
- water is captured by reservoirs, water wells, and intake points on streams and rivers for energy, industrial, agricultural, and drinking-water uses.

Nature's income typically is deposited at a variable rate. We get sporadic rains, then spring floods. Pounding summer thunderstorms splash water across the land. Then there are scorching days where rainstorms bubble up and dissipate in the afternoon sun. Snow events (big and little) come and go. The old slogan "When it rains, it pours," originally referred to Morton salt (Morton Salt, 2010) and its marketed capacity to pour even in high humidity, but it has also come to mean that you occasionally get more of something than you need, or you get something when you really don't want it. Such are the vagaries of precipitation.

Rain Gage

In an increasingly water-conscious society, we monitor parts of the hydrologic cycle to measure how much water we have at a given time, and to predict its movement from one phase to another. There are numerous ways to monitor hydrologic conditions. We measure rainfall and snowfall amounts, snow pack, streamflow and stream levels, humidity, dew point, soil moisture, the water table elevation, withdrawal rates and amounts, and reservoir levels. Water may be constantly in motion, but the exchanges don't occur at a steady rate. At times, some processes of the cycle accelerate while others slow or come to a stop. Water may be caught up in deep groundwater flow for thousands of years, or rainfall may evaporate before it reaches the ground (a phenomenon called virga). Other processes, like storms, quickly shift from one place to another. Specific events can be remarkable, often difficult to measure, and seemingly unpredictable.

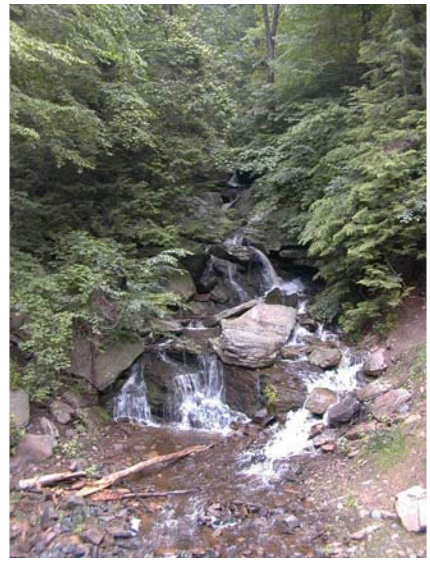
Sometimes the water cycle appears broken, and it gets our attention. For example, it's easy to notice when it doesn't rain for a couple of weeks in the summer. The grass turns brown. The forest floor gets crisp and tinder-ready. Stream and river levels drop. Is it a drought?

Cycle Down

In Pennsylvania, the Department of Environmental Protection (DEP) declares drought conditions on behalf of the governor and does much of the evaluation associated with a drought determination. The Pennsylvania Emergency Management Agency (PEMA) is responsible for managing water resources in a drought. A Drought Task Force, chaired by DEP and made up of representatives from state government and other relevant agencies that are directly affected by water shortages, works closely with DEP and PEMA in the event of a drought. These agencies consider numerous parameters like precipitation, streamflow amounts, groundwater levels, reservoir volumes, and soil conditions before making their drought-level recommendation.

There are three levels of drought: watch, warning, and emergency. The level depends on the indicators mentioned above and the degree of the situation. For example, the condition where streams are at only 5 to 10 percent of their average flows would indicate a warning level (Pennsylvania

Department of Environmental Protection, 2010). A drought emergency is the most severe situation, and specific water uses can be prohibited.



Measurements of water cycle processes used in drought management can be seen online. For example, the USGS provides a graphical view of streamflow amounts at WaterWatch (waterwatch.usgs.gov). One click on Pennsylvania brings up a map showing the percentile classes of streamflow for the 182 gages in the state. You can see tables that show the distribution of streams according to the percentile in which the streamflow occurs. For example, 97 percent of the 180 gages active on December 7, 2010, in Pennsylvania had streamflow rates that were greater than 25 percent of average flow. Another similar tool by the USGS provides data on groundwater levels (groundwaterwatch.usgs.gov). On January 21, 2011, it showed 69 real-time data points across the state.

The Climate Prediction Center of the National Weather Service provides weekly hydrologic assessments for the entire country. The products presented at their web site (www.cpc.ncep.noaa.gov/products/expert_assessment/drought_assessment.shtml), are based on numerous partners and data providers like the USGS, U.S. Department of Agriculture, and the National Oceanic and Atmospheric Administration. The National Weather Service also shows precipitation departure maps (www.erh.noaa.gov/marfc/Maps/precip.shtml).

Recognizing the onset of drought requires vigilance. For example, the year 2009 started on the dry side for most of the state, with the exception of northwestern Pennsylvania. March, the most important month for groundwater recharge in Pennsylvania (Reese and Risser, 2010), continued to be dry. By the end of April, precipitation amounts were almost 2 to 6 inches below the annual 30-year precipitation mean. But, thankfully, "average" rains returned in the spring. The deficit was erased without significant flooding or a major Atlantic hurricane, and the year ended with near-average precipitation statewide (southeastern Pennsylvania was actually 4 to 5 inches above normal, whereas southwestern Pennsylvania was 2 to 3 inches below normal).

In 2010, a dry spell from June through September prompted drought watches and warnings statewide. Then, a wetter October eased the worry about a drought. The warnings were lifted statewide, but a drought watch remained for the western third of Pennsylvania. The storm of November 30 through December 1 brought a soaking rain to most of the state. On December 17, DEP lifted the watch for the rest of the state (www.portal.state.pa.us/portal/server.pt/community/drought_information). Areas far south of Pennsylvania remained dry, especially along the Gulf Coast and west through Texas, where a severe drought persisted into the summer of 2011. In Pennsylvania, a wet March in 2011 soaked most of the state (see front cover), though parts of western Pennsylvania from Clearfield County to Venango and Butler Counties had below average streamflows in early April 2011. However, by the end of the month, both Williamsport and Harrisburg had set monthly precipitation records of 10.04 and 9.46 inches, respectively.

After the rains come, we quickly forget water shortages. As long as water flows from the tap, there is a tendency to be complacent and ignore the possibility of a sudden onset of drought conditions. In addition, increased water use also may be imperceptible to most Pennsylvanians. Unfortunately, we cannot supply any more water to the hydrologic cycle. The key lies in usage. Pennsylvania is a water-rich state, yet at times, demand for water can locally exceed supply, which causes problems. For example, it is being recognized that some level of water withdrawal for human use can hurt a watershed's instream flora and fauna. The withdrawal amount that affects a stream's biota is the subject of much study.

There are areas of the state where the water resources are getting pinched by heavy consumption and, perhaps, by thoughtless use. In 2002, the Pennsylvania Water Resources Planning Act was passed; this act required an update to the State Water Plan (Pennsylvania Department of Environmental Protection, 2011) for better understanding and management of Pennsylvania's water resources. During the process established through the State Water Plan, regional committees recently identified about 20 watersheds to be considered as possible "critical water planning areas." For these areas and others, will demand exceed supply? And what happens when a drought hits?

Unfortunately, we may be at the mercy of demand for more and more water and the unpredictability (beyond a few days or so) of precipitation. As population and use of our natural resources increase, we must plan the usage of our water resources not only to conserve but to sustain.

Save it for a Sunny Day

How can we save water? One obvious answer is conservation. Conserving water has many positive benefits. Typically, one saves money by using less water. For homeowners with their own well, there may be less wear on a water-well pump or a reduced need for water-treatment chemicals. For those with a water bill, lower use equals lower bills. For communities that manage large water systems, it could mean lower fees (well, theoretically!). Real water conservation keeps the water cycle healthier and sustains critical water users.

Through the State Water Plan, Pennsylvania has initiated a new effort to conserve water called "Save Water PA." Its mission is to promote voluntary efforts for water conservation while providing technical tools to help reduce water use in the state. This new strategy is a multi-pronged effort that considers various water users such as businesses, homeowners, farmers, utilities, and governments (www.savewaterpa.org).

Stewardship of natural resources is a goal most people agree on. An awareness of the need to conserve water will help to foster better ideas on how to manage water and to promote sustainability. Many agencies, such as river basin commissions, have already begun to operate with conservation principles in effect and with an eye on the erratic cycle. Like the income of a salesperson, disparity in precipitation amounts should be anticipated. We don't know in advance that seven lean years will follow seven years of abundance, but we can take advantage of high flows in anticipation of droughts.

Scott Bair, a Professor in the School of Earth Sciences at Ohio State University, prescribes "cheating the hydrologic cycle" as a way to strive for sustainability (Bair, 2008). In essence, his prescription is to create purposeful interconnections in the cycle to meet future demands. He proposes techniques like "induced infiltration" from streams or creating artificial recharge zones to withdraw and store water for future use. So, in the hydrologic cycle, he would increase the infiltration and recharge, while decreasing the proportion of runoff and evaporation-transpiration. He is rethinking the hydrologic cycle.

When you look at the hydrologic cycle and monitor the percentages that are represented, you see that there are times when the supply is high. Heavy rains come, rivers and streams run bank-full, and water rushes downstream while riverside communities brace for flooding. This is the moment when water "takings" have little impact on stream life and use. In addition, timely takings and storage enhance our ability to sustain water withdrawals.

This philosophy is being used by the Susquehanna River Basin Commission to diminish impacts of water takings from streams and rivers. For stream withdrawals, the commission uses a "passby" flow requirement. If water levels are too low, the user cannot pull water from the stream. This procedure encourages the user to withdraw water when it is plentiful, much like a homeowner who uses a rain barrel to collect excess rainwater off the roof for later use. When it rains, it stores.

Another important consideration is land use. When we pave over land, we also short-circuit part of the hydrologic cycle by sending water to runoff that might have otherwise infiltrated to the subsurface. In the long run, is it possible that putting developments on natural recharge areas like the linear ridges of Pennsylvania could be harmful?

An understanding of the water cycle and its interrelated parts allows for recognition of opportunities to conserve water. Rethinking the water cycle can be a way to improve the management of our most precious resource—water.

Acknowledgments

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The New 1:100,000-Scale Map of Pennsylvania Glacial Features

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In recent years, Elsevier has published a series entitled *Developments in Quaternary Science.* A three-volume set in the series, *Quaternary Glaciations—Extent and Chronology*, edited by Juergen Ehlers and Phillip Gibbard, was published in 2004 and provided a global map of glaciation with printed text and 1:1,000,000-scale digital maps in ArcView format on CDs. North America was covered in Part 2, and I was responsible for the Pennsylvania portion of the map (Braun, 2004). The information in the volumes was assembled from 1995 to 1999, however, and with the rate of new information being produced, it was soon apparent that it was time for an updated global glaciation map (publication planned for August 2011) (Figure 1). The amount of information available had also increased, so a scale of 1:100,000 was chosen for the updated map. In December 2009, I drafted my interpretation of the glacial features on the eighteen 1:100,000-scale sheets (nine complete and nine partial) that cover the portion of Pennsylvania that was glaciated. These are not glacial deposit maps, though prominent moraines, kames, and eskers are shown, but rather they emphasize glacial features such as different ages of glacial borders or limits, proglacial lake outlines, and outlet sluiceways. The editors of the volume are converting my hand-drawn sheets into ArcGIS digital files, which will be included as part of the global map. The map will be produced as a set of DVDs in the back of a single 1,000-page text volume.

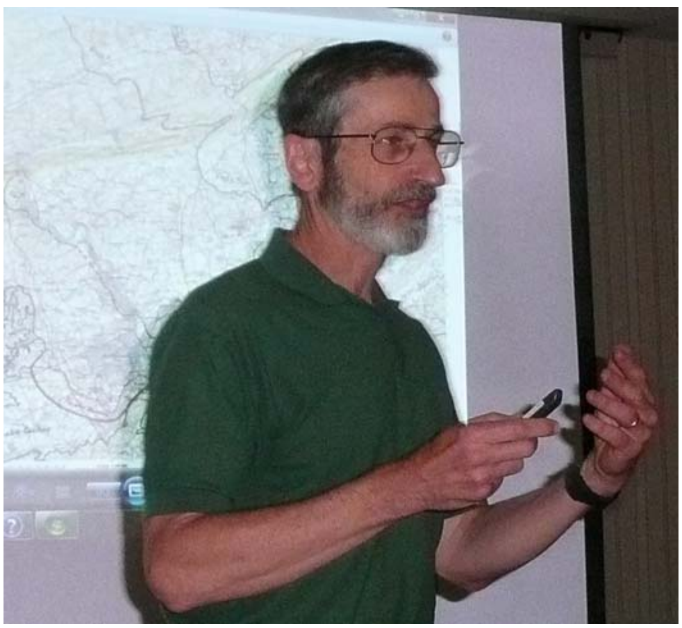

Figure 1. Duane Braun gave a talk about his work on the soon-to-be-published global glaciation map at a Brown Bag Seminar in the Middletown office of the Pennsylvania Geological Survey on May 7, 2010.

There are four different ages of glaciation shown on the new Pennsylvania glaciation map (Braun, in press), labeled by internationally recognized Marine Isotope Stage (MIS) or Oxygen Isotope Stage numbers rather than the traditional North American glacial stage names such as the Wisconsinan. The current MIS record on the *Global Chronostratigraphical Correlation Table for the Last 2.7 Million Years* (Gibbard and Cohen, 2009) indicates four pre-Wisconsinan cold events equal to or greater than the late Wisconsinan during the last million years. Thus, there may still be one more not-yet-recognized pre-Wisconsinan glacial event that advanced beyond the late Wisconsinan terminus. The oldest glacial advance now recognized in Pennsylvania is early Pleistocene, MIS 22 (880 ka) or older in age. Glacial lake sediments of that advance have a reversed magnetic polarity (Jacobson and others, 1988; Gardner and others, 1994; Sasowsky, 1994; Marine, 1997; Ramage and others, 1998) and are thus more than 788 ka old. It is probable that the next younger glacial advance is middle Pleistocene MIS 16(?) (630 ka) age. Glacial lake sediments of that advance have a normal magnetic polarity (Sasowsky, 1994) and thus are younger than 788 ka. The next younger glacial event is the MIS 6 (150 ka) (Illinoian) or 12 (420 ka) advance (labeled on the maps as 6-12?). This glacial advance has traditionally been thought to be MIS 6 or late Illinoian in age (Leverett, 1934; Sevon and others, 1975; Marchand, 1978; Berg and others 1980; Braun, 1988). However, the relatively great amount of weathering and erosion of deposits from this advance in northeastern Pennsylvania means that it is doubtful that just 150,000 years have elapsed since the material was deposited (Braun, 1999, 2008). Thus, it has been suggested that what was thought to be a MIS 6 event is actually a MIS 12 event (Braun, 2004, 2008). A MIS-12-aged advance would permit about another 300,000 years to weather and erode the deposits. Finally, the most recent glacial event is the 25-ka-aged (calibrated calendar years) (Ridge, 2003) MIS 2 or late Wisconsinan advance.

In northeastern Pennsylvania, the moderate relief (300 to 500 meters) on sandstone bedrock produced a dominance of erosion over deposition in each glacial advance (Braun, 1989, 1994, 2006). Each advance left thick glacial and proglacial deposits in the valleys, while adjacent ridge crests are essentially bare bedrock. Portions of the preglacial stream drainage were to the east or northeast, and glacial advance blocked that drainage to form Glacial Lakes Lesley (Williams, 1902) and Packer (Williams, 1894) (Figure 2) at the early Pleistocene glacial limit. Other proglacial lakes were impounded along that limit, along younger limits (Fuller and Alden, 1903; Braun, 1988), and north of the late Pleistocene limit as ice receded from Pennsylvania (Coates, 1966; Braun, 1989, 2002; Gardner and others, 1993; Braun and Kochanov, 1996). Part of the drainage was diverted to form the "Grand Canyon of Pennsylvania," a 425-meter-deep bedrock gorge (Fuller and Alden, 1903; Crowl, 1981). In the future, much of the northeast-trending drainage will be turned southward if other glaciations deepen existing glacial meltwater sluiceways.

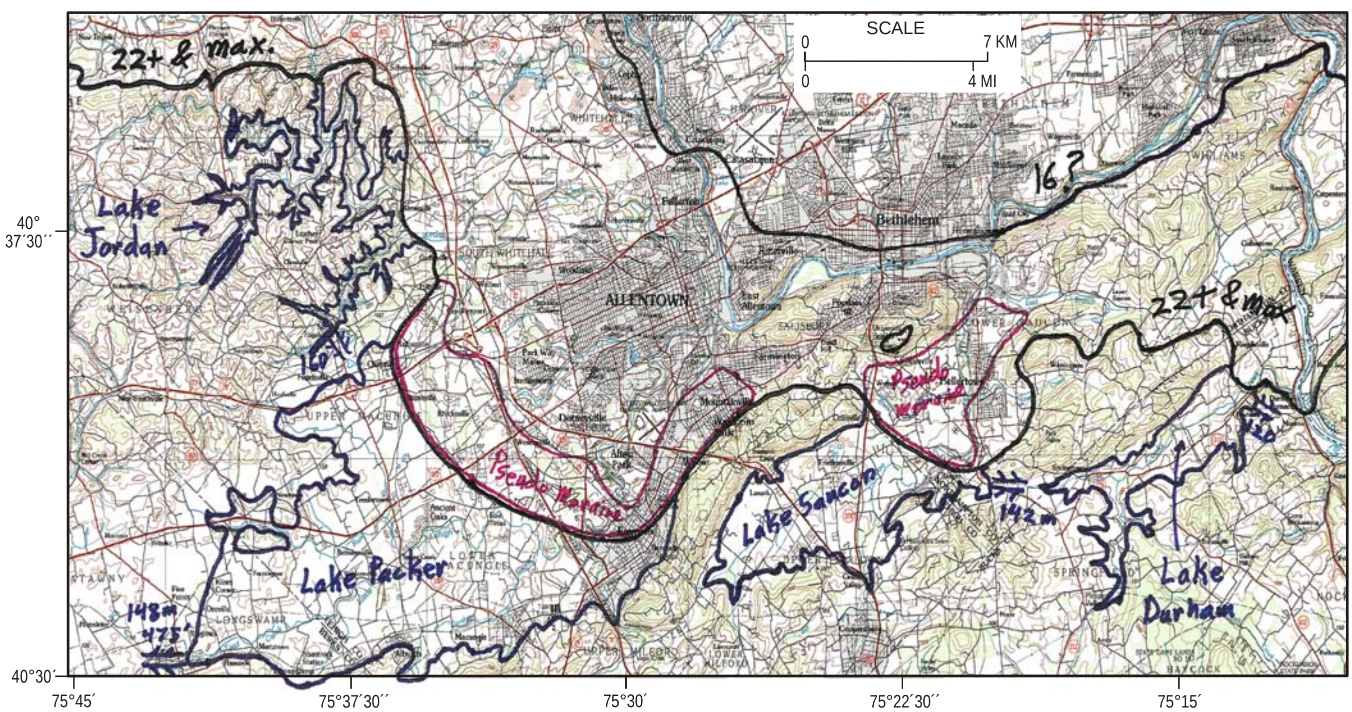

Figure 2. Map showing patches of pseudo-moraines and proglacial lakes along the MIS 22+ glacial terminus in the Allentown area (base map from the south-central part of the U.S. Geological Survey Allentown 1:100,000-scale metric topographic map).

For northeastern Pennsylvania, a number of features not shown on previous maps will be shown on the new glacial map. A few examples of these features are illustrated in Figures 2 through 8. In the Allentown area are patches of what was once thought to be true glacial moraine (Leverett, 1934) but what are now considered to be "pseudo-moraine," old MIS-22+-aged glacial deposits "captured" by limestone dissolution (Figure 2). The morainelike topography is glacial material draped over karst with smaller scale periglacial features on the flanks of the sinkhole depressions (Braun and Kochanov, 1996; Braun, 1999, 2004, 2008).

On the Pocono Plateau, there are eskers that cross most of the plateau and end at the MIS 2 terminus (Figure 3). Much of the northern part of the Pocono Plateau was occupied by the five stages of Glacial Lake Wallenpaupack, each stage draining out successively lower outlets in different directions (Figure 4).

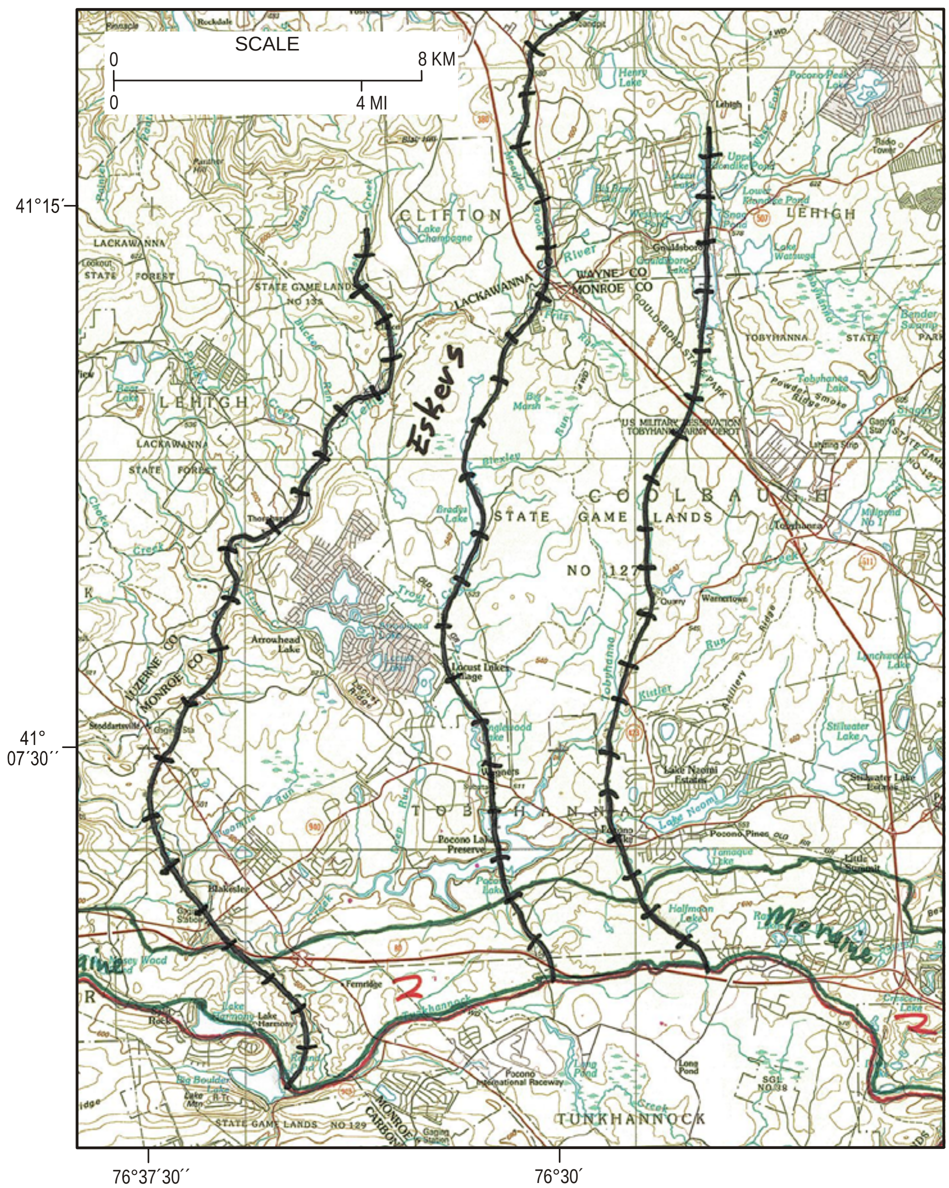

Figure 3. Map showing eskers (black tick-marked lines) crossing the Pocono Plateau (from the south-central part of the U.S. Geological Survey Scranton 1:100,000-scale metric topographic map).

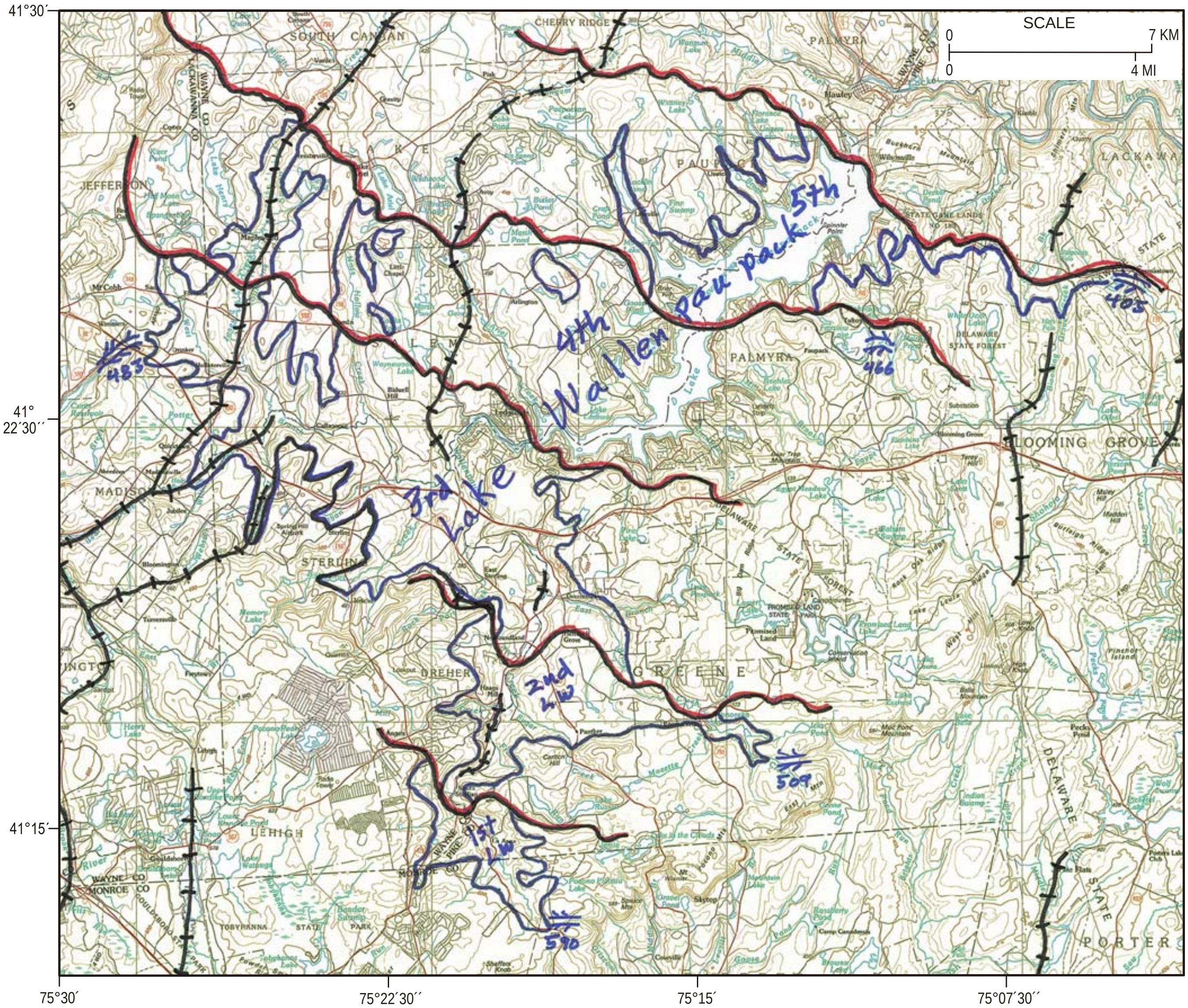

Figure 4. Map showing the five different water-level stages of Glacial Lake Wallenpaupack (from the northeastern part of the U.S. Geological Survey Scranton 1:100,000-scale metric topographic map). The first two lake stages drained southeast to the Delaware River; the third stage drained southwest to the Susquehanna River; and the fourth and fifth stages drained east to the Delaware River.

In north-central Pennsylvania, the entire north-draining Cowanesque, Tioga, and Pine drainages were impounded in a series of large proglacial lakes, the largest of which was Glacial Lake Mansfield (Figure 5). This lake was so deep that only the hilltops around Mansfield stuck out as islands in the lake. Additionally, glacial-lake clays may be found high on the hillslopes and cause hillslope failure if disturbed by human excavation activities. Other large proglacial lakes in north-central Pennsylvania occupied the Allegheny drainage headwaters during MIS 22+, 16(?), and 6-12 advances as is shown by clay in borehole records (Lohman, 1939). In northwestern Pennsylvania those same glacial advances terminated just north of the present site of the Kinzua dam and impounded a proglacial lake in the north-draining Allegheny valley. Downwarp of the land surface near those early glaciations lead the Kinzua site to be the meltwater outlet that was incised to divert the Allegheny River southward (Figure 6).

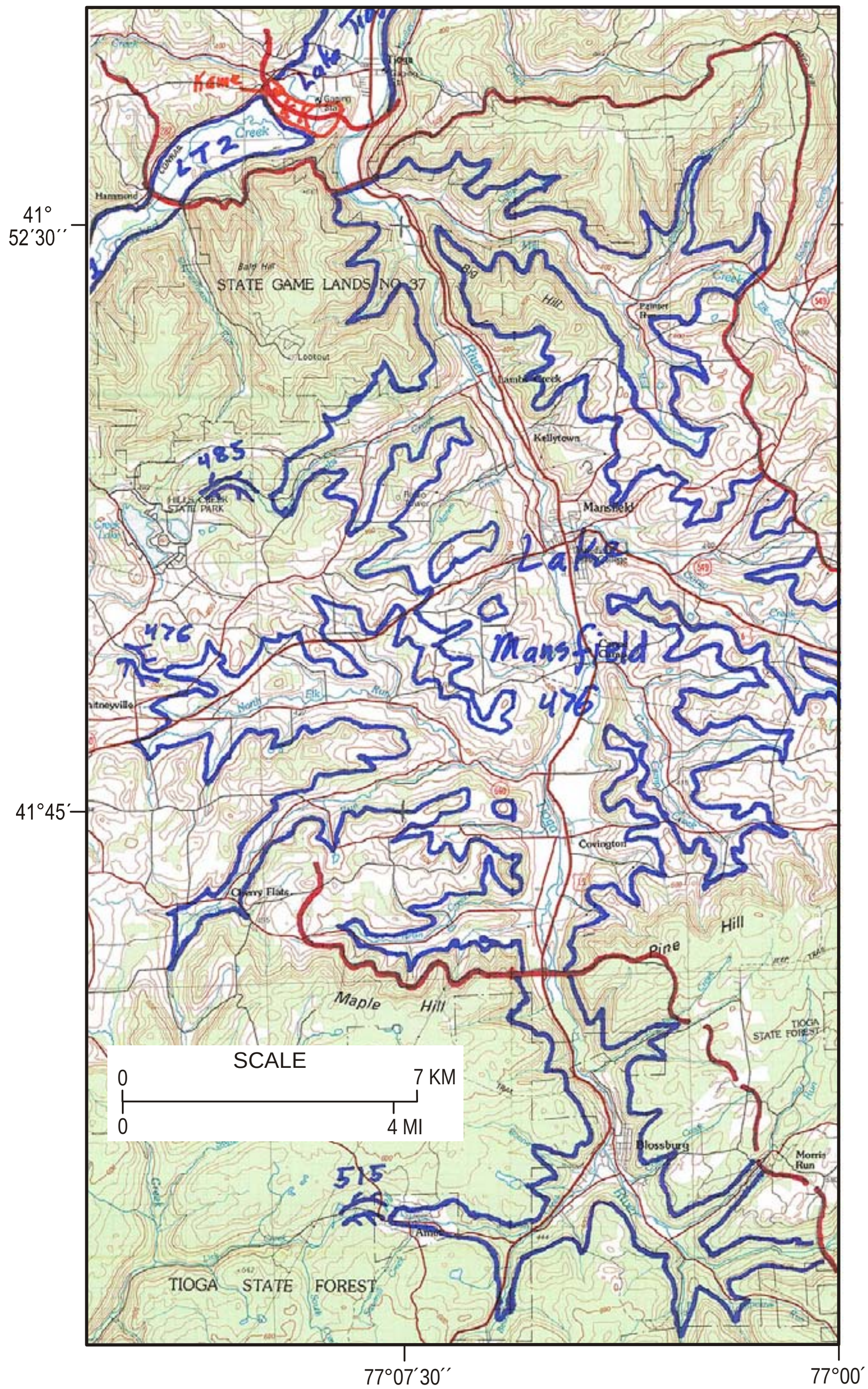

Figure 5. Map showing the broad extent and depth of Glacial Lake Mansfield (from the east-central part of the U.S. Geological Survey Wellsboro 1:100,000-scale metric topographic map). The blue numbers are the floor elevations of the sluiceways and lake levels in meters.

Throughout northwestern Pennsylvania, the relatively low relief (100 to 300 meters), shaly bedrock, and abundant debris from the Great Lakes basins resulted in a dominance of deposition over erosion in each glacial advance. Therefore, the new glacial map will show extensive areas of glacial moraine and kame deposits, primarily as mapped by Shepps and others (1959), but with revised recessional ice margin positions extended southwesterly from New York ("2r lines" on Figure 7).

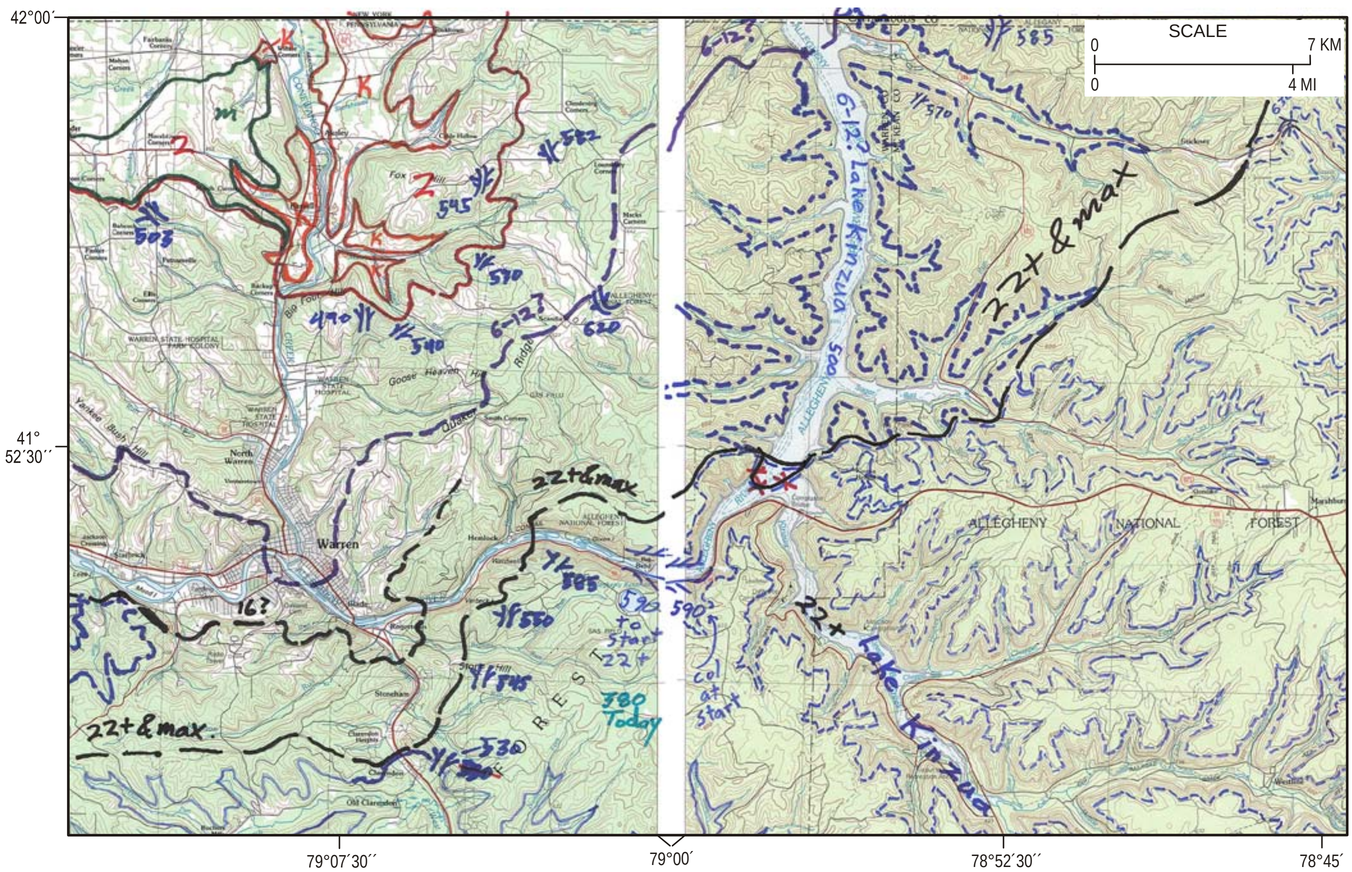

Figure 6. Map showing the closely spaced glacial limits in the Kinzua col area east of Warren, Pa. (from the northwest corner of the U.S. Geological Survey Bradford 1:100,000-scale metric topographic map and the northeast corner of the Warren 1:100,000-scale metric topographic map). The blue numbers are the floor elevations of the sluiceways and lake levels in meters, red number 2 is MIS 2, and K indicates kame or ice-contact stratified drift sand and gravel deposits. There is a gap between the two maps in order to show all of the handwritten notations.

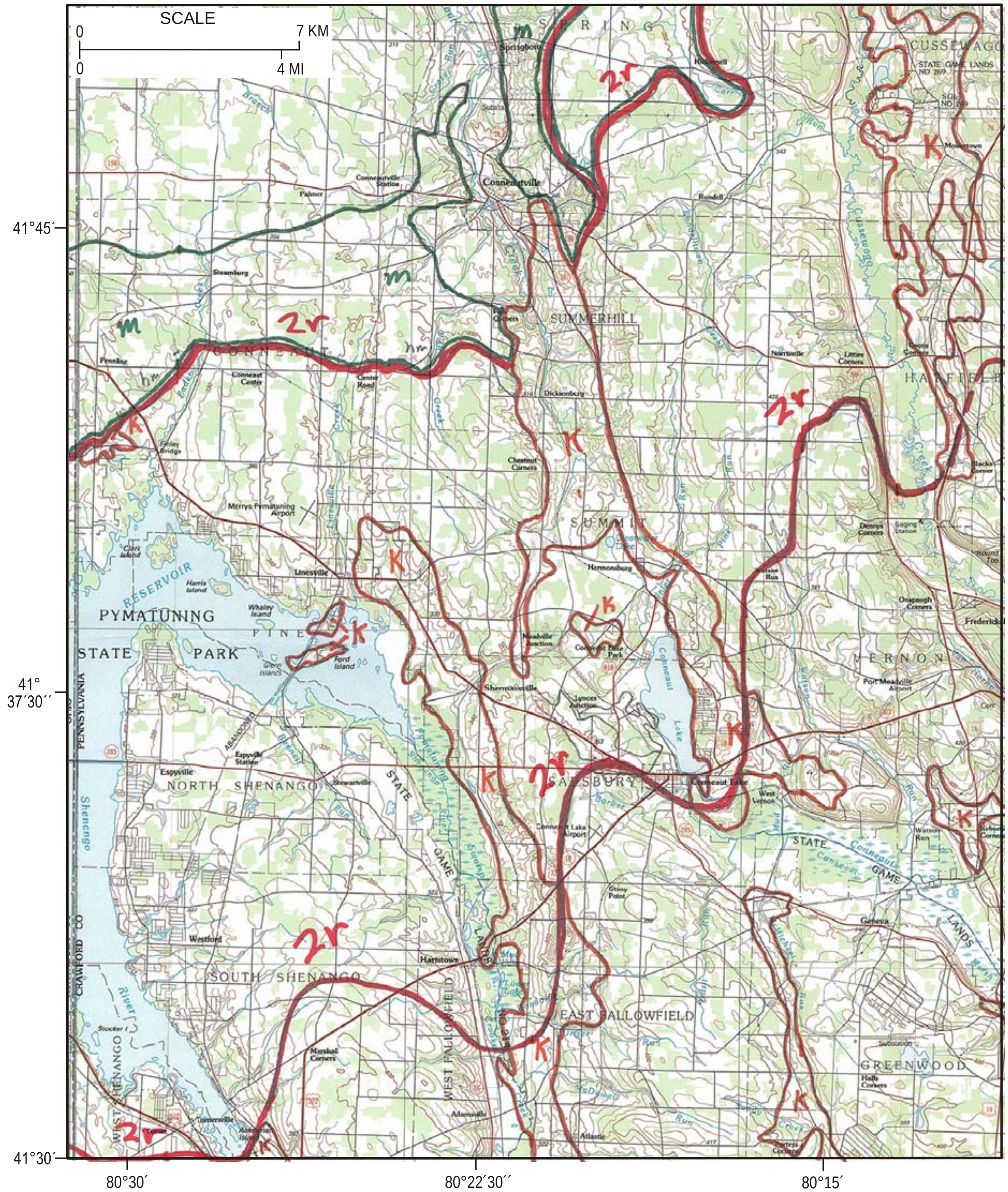

Figure 7. Map showing the recessional ice margins (in part, actual moraines) bracketing the present Pymatuning Reservoir (from the south-central part of the U.S. Geological Survey Ashtabula 1:100,000-scale metric topographic map). The ice margin on the north side of the reservoir is considered to be the southwest extension of the Findley Lake margin, while the ice margin on the south side of the reservoir is considered to be the southwest extension of the Clymer. Both margins were defined in westernmost New York by Muller (1977) and extended by him just into northwestern Pennsylvania. The red lines and numbers (2r) are MIS 2 recessional ice positions, and K indicates kame or ice-contact stratified drift sand and gravel deposits.

The preglacial stream drainage in western Pennsylvania was to the northwest and was blocked and diverted to the southwest by each of the glaciations to form an ice marginal drainage system, the present Allegheny-Ohio River system (Carll, 1880; Leverett, 1902, 1934; Kaktins and Delano, 1999). The early Pleistocene and probably early-middle Pleistocene glaciations impounded large proglacial lakes, especially Glacial Lake Monogahela (Figure 8), whose deposits are widespread in valleys in south-western Pennsylvania and northern West Virginia (White, 1896; Campbell, 1903; Leverett, 1902, 1934; Lessig, 1963; Jacobson and others, 1988). The maximal extent of the oldest glacial advance (MIS 22+) is now thought to have been south of the Beaver-East Liverpool reach of the Ohio River (Figure 8).

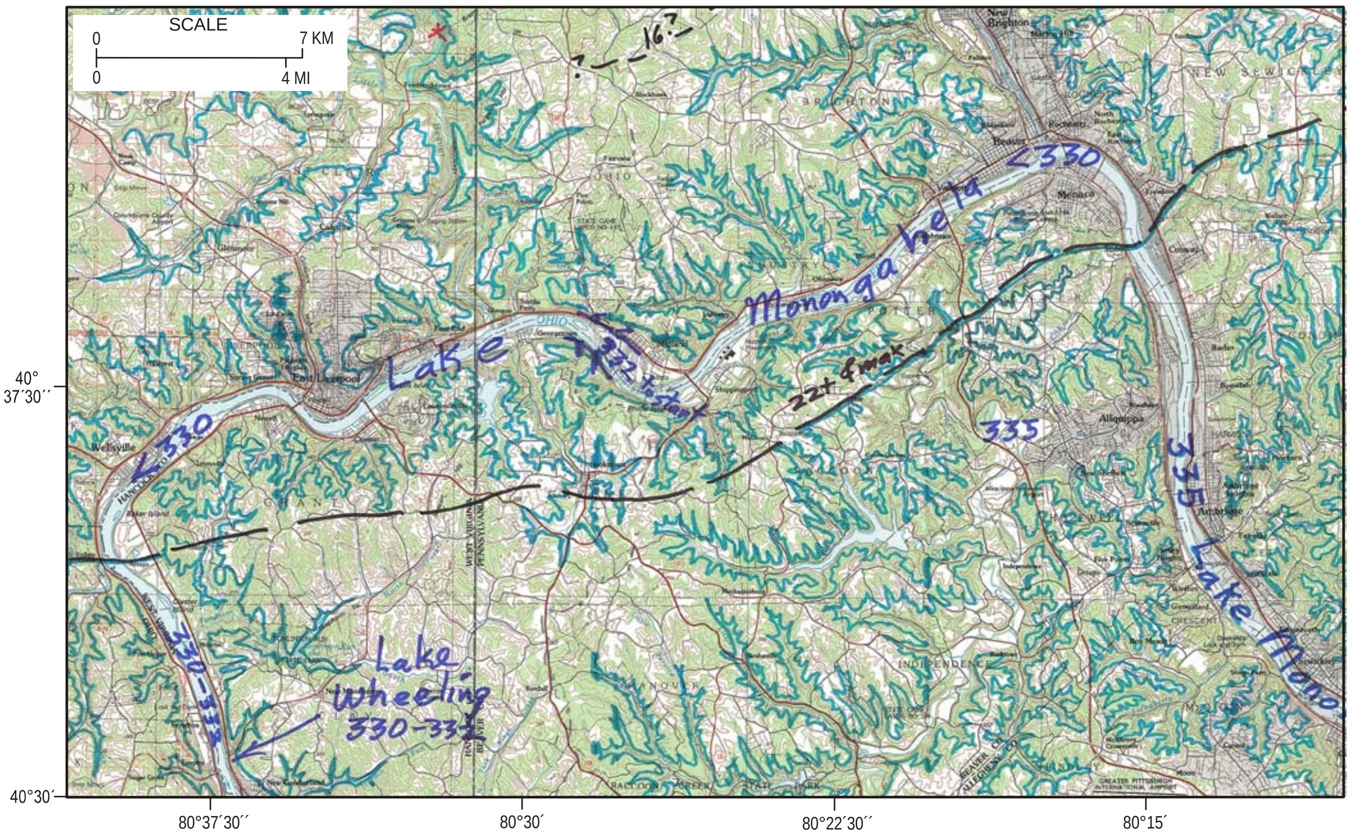

Figure 8. Map showing the proposed position of the MIS 22+ glacial terminus south of the Beaver-East Liverpool reach of the Ohio River (from the south-central part of the U.S. Geological Survey East Liverpool 1:100,000-scale metric topographic map). The MIS 22+ terminus was placed there to hold in the initial 1,100-foot Glacial Lake Monongahela. The blue numbers are the floor elevations of the sluiceways and lake levels in meters.

This maximal extent would have permitted cutting of meltwater sluiceways both at the head of the Monongahela drainage in West Virginia (White, 1896) and near New Martinsville in West Virginia that is a few feet to tens of feet lower. Initial recession of the MIS 22+ glacier would have then opened up the Beaver-East Liverpool reach and initiated the cutting of the sluiceway at Midland, Pa. The newly cut sluiceway would have formed a slightly lower, longer lived Glacial Lake Monongahela draining across both the Midland and New Martinsville cols. Those cols would have been deepened by the MIS 16(?) glaciation, possibly to near their present level, and they would have been fully cut by the MIS 6-12 glaciation (Leverett, 1902, 1934).

The new 1:100,000-scale Pennsylvania glacial features map shows the limits of four glacial advances rather than three as on the previous map by Sevon and Braun (1997). In northeastern Pennsylvania, features shown are pseudo-moraine areas of MIS 22+ age, lengthy eskers of MIS 2 age, and a number of large proglacial lakes. In north-central Pennsylvania, much of the area was covered by proglacial lakes of MIS 22+ to MIS 2 age. In northwestern Pennsylvania, extensive areas of sand and gravel kames and till moraine are shown along with revised limits to the various glacial advances. In addition, in northwestern Pennsylvania a number of very extensive proglacial lakes led to the formation of the ice marginal Allegheny-Ohio River alignment.

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An Update on Laboratory Equipment

John H. Barnes
Pennsylvania Geological Survey

The last time that we reported on technological changes in the bureau (Barnes, 2003), the news was that we had just added a scanning electron microscope (SEM) to our laboratory. The SEM replaced an X-ray fluorescence spectrograph that was acquired in 1969 (Pennsylvania Geological Survey, 1970). We reported that we expected the SEM to be valuable in giving us new capabilities in our study of Pennsylvania's geology. It has, indeed, been of use in a number of projects as well as in answering requests for data from other state agencies, such as the Department of Environmental Protection and the Pennsylvania Historical and Museum Commission.

Since the article on the SEM was written, we have added, and are in the process of adding, a number of other new tools to our laboratory. The first was an accessory for the SEM called a cathodoluminescence (CL) detector, which we acquired in 2007. This detector measures the light that is given off by a sample when it is energized by the SEM's electron beam. We quickly put this to use in connection with studies of carbonate rocks that serve as hydrocarbon reservoirs. Using CL, it is possible to recognize different generations of crystallization in the minerals calcite and dolomite, which make up the rock, helping us to better understand the history of its formation (Figure 1). This, in turn, has implications in evaluating the rock as a reservoir. In addition to this application, the CL detector has other uses that we look forward to exploiting in the future.

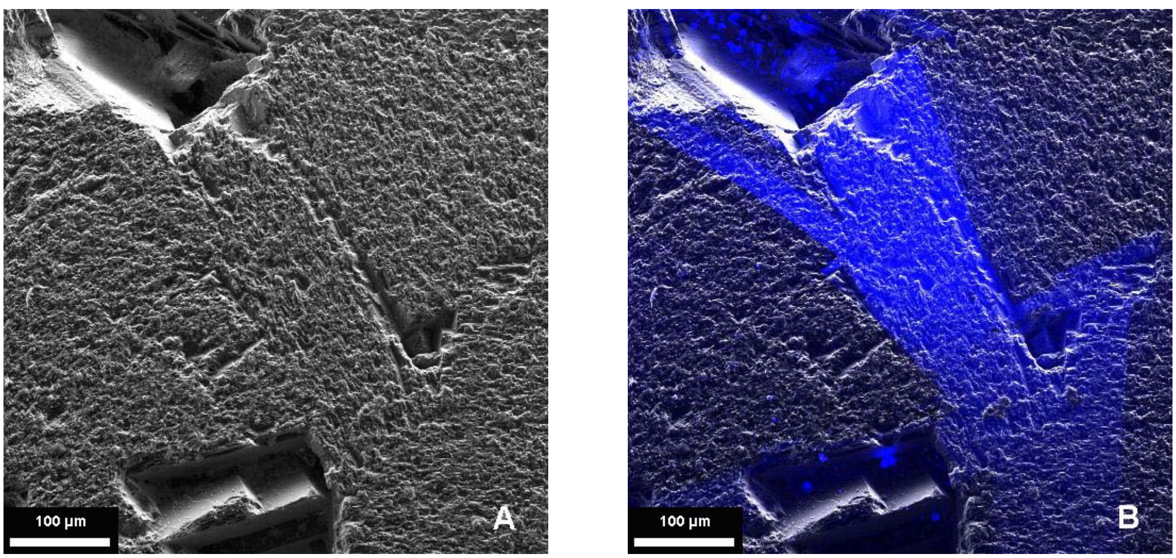

Figure 1. A. Standard low-magnification photomicrograph of carbonate rock, obtained using the bureau's scanning electron microscope (SEM). B. The same area showing data captured using the bureau's cathodoluminescence (CL) detector overlain on the SEM image. The CL can be tuned to different wavelengths (colors) of light, and here it shows an area emitting blue light. This indicates a different generation of crystallization than the surrounding rock, which is not emitting light.

Several new microscopes have also been added recently. Two were purchased to improve upon existing capabilities. One is a stereoscopic microscope that is used to examine and photograph hand specimens that contain interesting minerals or fossils. The other is a petrographic, or polarizing, microscope that is used to study thin sections (very thin slices of rock through which light can pass). Both are basic tools in any geology lab. These new microscopes provide not only a clearer view by using better optics but also advanced digital-imaging capabilities that allow improved methods for documenting and reporting our work.

A new capability will be gained when we have completed acquisition of equipment that will allow the preparation and study of rocks that contain organic substances, which in turn tells us about their thermal history. The new items include specialized microscopes that are connected to devices called photometers that precisely measure the amount of light that is reflected from a sample. Both our Middletown and Pittsburgh offices now have such microscopes. Additional specialized equipment to prepare the samples is presently on order and will complete the package.

Finally, in our previous articles (Pennsylvania Geological Survey, 1970; Barnes, 2003), it was mentioned that the bureau has maintained X-ray diffraction instrumentation since 1957. Although that equipment has undergone some upgrades since that time, first to switch from vacuum tubes to solid state electronics, and later to switch from recording data on paper charts to recording it as computer files, the basic equipment for creating and measuring the diffracted X-ray beam has remained the same since 1957. That is about to change, as the bureau has just acquired a completely new and modern X-ray diffractometer (Figure 2). The greater resolution and sensitivity of this equipment should allow more accurate identifications of the individual mineral components that make up a sample. Coupled with its more efficient operation, we will be better equipped to meet the needs of our internal project support activities and respond to requests from other agencies for X-ray data. Also, with this equipment we expect to be able to once again work with very small samples, a capability that we lost when film manufacturers (responding to the digital revolution) ceased production of the specialized X-ray film that was required to study such samples using our old equipment. The modular design of the new equipment will allow us to add features to increase its capabilities over time. We expect it to serve our needs well for many years into the future.

Figure 2. The bureau recently replaced its aging X-ray diffractometer with this up-to-date unit.

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Another Milestone for the Pennsylvania Geological Survey

Leonard J. Lentz
Pennsylvania Geological Survey

This year marks the 175th anniversary of the Pennsylvania Geological Survey. There have been four “Surveys” of the Commonwealth of Pennsylvania during those 175 years, a result of the legislature ending and then resurrecting the Geological Survey several times. These recurring surveys are briefly described in the next paragraph. The current bureau organization is actually the Fourth Geological Survey, commissioned by the legislature in 1919 to measure, describe, and report on the topography and geology of the state (to briefly paraphrase our mission statement). The Fourth Survey recently celebrated its own 90th anniversary in 2009. The Pennsylvania Geological Survey was one of the first geological surveys in the country and is one of the oldest agencies in Pennsylvania’s state government.

Created by an act of the legislature on March 29, 1836, the First Geological Survey of Pennsylvania was to provide for a “Geological and Mineralogical Survey” of the state. Henry Darwin Rogers was the first State Geologist. At that time, it was anticipated that a geological survey of the state could be completed in 10 years. Instead, 22 years later, two immense (1,631 pages total) illustrated volumes of geologic studies and a first-ever geologic map of the state were finished. After a 16-year hiatus, in 1874 the legislature once again commissioned a “new” geological survey, now known as the Second Geological Survey. J. Peter Lesley served as the State Geologist. This Second Survey produced numerous volumes, including many of the invaluable county reports, especially of the Anthracite region, which are still used for reference today. This process would be repeated yet again. After a 20-year hiatus, in 1909 a Topographic and Geological Survey Commission was authorized by the legislature. This Third Geological Survey was tasked with cooperating with the U.S. Geological Survey, which was founded 30 years earlier in 1879, and it focused on mineral resource studies during its brief 5-year existence. Richard R. Hice was the State Geologist. In 1919 the legislature once again mandated a new survey of the state, thus creating the current Bureau of Topographic and Geologic Survey, or Fourth Survey. The Fourth Survey represents the longest continuous operation of the Pennsylvania Geological Survey since its inception 175 years ago. It is also perhaps the most diverse Survey ever, producing a wide range of studies from groundwater and energy resources to earth science education and geologic hazards. Its mission has evolved with the times as the needs of society have changed. During this long continuous span of activity, the Fourth Survey has been managed by several State Geologists, starting with George H. Ashley in 1919. Others who have served are Ralph W. Stone, Stanley H. Cathcart, Carlyle Gray, Arthur A. Socolow, Donald M. Hoskins, Jay B. Parrish, and our current State Geologist, George E. W. Love (see the announcement on the next page).

Carlyle Gray, State Geologist, 1953–1961.

We are proud to mark 175 years of service to the geological profession and, foremost, to the citizens of the Commonwealth of Pennsylvania.

SURVEY NEWS

Pennsylvania Has a New State Geologist

George Love was recently appointed to the position of Director, Bureau of Topographic and Geologic Survey. Love had been serving as the Assistant Bureau Director since joining DCNR after retiring from Carmeuse North America in 2006. Love will function as the State Geologist of Pennsylvania and be responsible for directing the activities of the bureau's professional, technical, and administrative staff. His more than 30 years of experience in executive leadership includes positions in mining, minerals, exploration, permitting, geology, and geotechnical engineering in private industry and government. Love has led up to 240 workers with an overall operating budget of $37 million. He has a Master's degree in geology and numerous credits in civil engineering and soil mechanics.

Love was born in Panama and still has family there. He is married and has three children and several grandchildren, who live in Texas, Tennessee, and California.

Former State Geologist Jay Parrish stepped down in September and is now teaching remote sensing online at the Dutton Institute at the Pennsylvania State University.

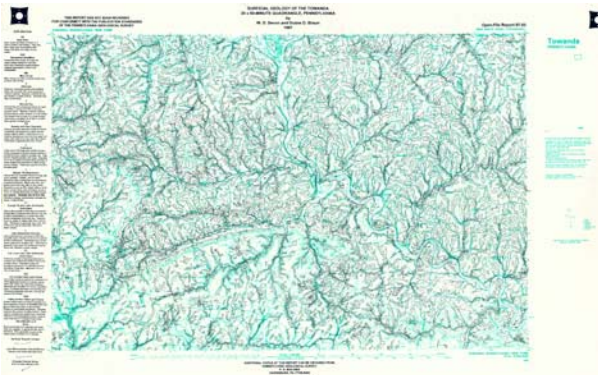
An Even Exchange: Pennsylvania State Bookstore Closed, Website Open

The Pennsylvania State Bookstore is no longer open. However, the Pennsylvania Historical and Museum Commission and the Pennsylvania Heritage Society now operate a web-based bookstore, located at pabookstore.com. This means that any of the available cost publications printed by the Pennsylvania Geological Survey can be ordered by a few clicks of the mouse. Just click on "PA State Publications" on the left navigation bar, and then click "Conservation and Natural Resources." You can then choose a report series and from there select the publications of interest. Clicking on "About us" on the menu bar at the top of the page will give you contact and shipping information.

NEW RELEASES

Marcellus Region Surficial Geology Reports

Two open-file reports published in 1997 and originally only available as photocopies of maps and text that are kept on file at the Survey's Middletown office are now available online. OF 97–02 and OF 97–03 show the surficial geology of the Wellsboro and Towanda 30- by 60-minute quadrangles, respectively, as mapped by W. D. Sevon (Pennsylvania Geological Survey, retired) and Duane D. Braun (Bloomsburg University, Professor Emeritus). The Wellsboro report also includes the Oswayo Creek area in the Bradford quadrangle to the west of the Wellsboro quadrangle.

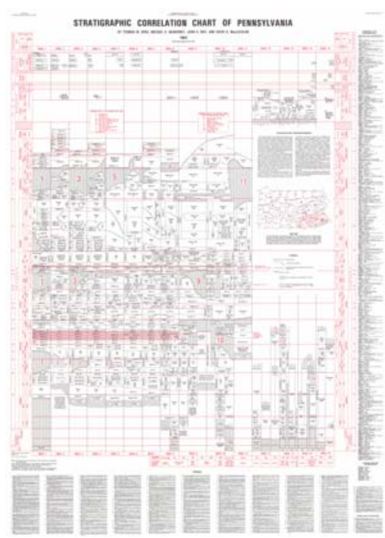


The reports consist of a map and an informative shared 25-page text. On the 1:100,000-scale maps, the surficial geology is outlined in black on a greenline mylar of a metric-contoured topographic base map.

Because of their location in the northern tier of the state where there is much interest in the Marcellus, the maps are in great demand. Accordingly, they have been scanned and made available online as PDF files for viewing or downloading, and as georeferenced JPG files, which can be downloaded and used in geographic information systems.

Correlation Chart of Pennsylvania

General Geology Report 75, the "Stratigraphic Correlation Chart of Pennsylvania," is now available online. It is a correlation diagram of lithostratigraphic units of Pennsylvania shown within a chronostratigraphic framework of North American and "global" subdivisions. The chart has 15 columns representing 15 areas in Pennsylvania. Rock units in Pennsylvania range in age from Precambrian through Quaternary, and all periods of the Phanerozoic Eon are represented. The publication includes an extensive reference list (almost 300 references).



The chart was first published in 1983 and was reprinted with revisions in 1986 and again in 1993. It is the third printing that is represented here. The downloadable files include images of the chart, a two-page addendum (an annotated bibliography for the latest round of revisions), and the envelope cover. Contact information at the top of the addendum has been updated on the scanned image.

G 75 is not out of print and is still available from the State Bookstore website. To order, go to the website at pabookstore.com.

RECENT PUBLICATIONS

Surficial geology open-file reports: **(April 2011)**

- Surficial Geology of the Long Eddy and Callicoon 7.5-Minute Quadrangles, Wayne County, Pennsylvania
- Surficial Geology of the Hancock 7.5-Minute Quadrangle, Wayne County, Pennsylvania, and Broome County, New York

Surficial geology open-file reports: **(December 2010)**

- Surficial Geology of the Blossburg 7.5-Minute Quadrangle, Tioga County, Pennsylvania
- Surficial Geology of the Liberty 7.5-Minute Quadrangle, Lycoming and Tioga Counties, Pennsylvania

Surficial geology open-file reports: **(November 2010)**

- Surficial Geology of the Orson 7.5-Minute Quadrangle, Susquehanna and Wayne Counties, Pennsylvania
- Surficial Geology of the Lake Como 7.5-Minute Quadrangle, Wayne County, Pennsylvania, and Delaware County, New York

Surficial geology open-file report: **(October 2010)**

- Surficial Geology of the Sugar Lake 7.5-Minute Quadrangle, Crawford and Venango Counties, Pennsylvania

Oil and gas geology open-file report: **(October 2010)**

- Chemistry and Origin of Oil and Gas Well Brines in Western Pennsylvania

GEOFACTS

The Peculiar Habits (and Observations) of Geologists

James R. Shaulis
Pennsylvania Geological Survey

Obtaining core

Geofact 12

When the core smiles back at you, one of the following may be the reason:

A. That 10 percent hydrochloric acid (used to determine the presence of calcite in a rock) just feels so good.

B. Corrugated cardboard is very comforting.

C. You have logged (analyzed) core a little too long.

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