VOL. 29, NO. 4

Pennsylvania GEOLOGY

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ON THE COVER

Items knocked off the shelves at the Golden Dawn Supermarket, Jamestown, Pa., by the Pymatuning earthquake (see article on page 2). Photograph by Regis Shawkey, September 25, 1998.

PENNSYLVANIA GEOLOGY

PENNSYLVANIA GEOLOGY is published quarterly by the Bureau of Topographic and Geologic Survey, Pennsylvania Department of Conservation and Natural Resources, P. O. Box 8453, Harrisburg, PA 17105–8453.
Editors: Anne B. Lutz, Christine E. Miles, and Donald M. Hoskins.
Contributed articles are welcome. Guidelines for manuscript preparation may be obtained through the Internet at URL <www.dcnr.state.pa.us/topogeo/mag-ins.htm> or by contacting the editors at the address listed above.

VOL. 29, NO. 4 **WINTER 1998**

STATE GEOLOGIST’S EDITORIAL

A Natural Geologic Event

On September 25, 1998, a natural geologic event—an earthquake—occurred in Pennsylvania. This natural event was significant for two reasons. First, its magnitude (5.2) was the highest ever recorded in Pennsylvania. Second, it occurred in an area of western Pennsylvania that only rarely experiences such events. Most prior Pennsylvania earthquakes of appreciable magnitude have occurred in or near Lancaster County in southeastern Pennsylvania.

The September 25 earthquake epicenter was located near the Crawford County community of Greenville, close to the Ohio-Pennsylvania border and near the south end of Pymatuning Lake, from which has come its name.

Much of this issue of *Pennsylvania Geology* is devoted to a description of the Pymatuning earthquake and the efforts by geologists and hydrogeologists to explain it and its effects. Some of the descriptions are technical but necessary to accurately portray the event.

However, the story of this earthquake has not ended with this issue, because we continue to track and investigate its results, which affected at least one of Pennsylvania’s most precious resources—its groundwater. As is described herein, many water wells that provide this important resource for household use were damaged. Many homeowners were required to drill new wells or deepen existing wells at significant personal cost.

Within a few days of the event, using the new digital technology of the World Wide Web, a web page was created and “published” by geologists of the U.S. Geological Survey (USGS). For more information than can be presented in this issue, please visit this web site at *<http://groundmotion.cr.usgs.gov/pym/pym.htm>,* as well as the companion web page provided by the Pennsylvania Bureau of Topographic and Geologic Survey at *<http://dncr.state.pa.us/topogeo/hazards/greenville.htm>.* As more information is obtained through continuing cooperative investigations by the USGS and Bureau hydrogeologists, it will be provided on these web sites.

In cooperation with the USGS and adjoining state geological surveys, we have developed a detailed database of recorded and historical earthquake events. A map of earthquake epicenters based on this database is available at *<http://dcnr.state.pa.us/topogeo/hazards/epimap.gif>.*

Donald M. Hoskins

Donald M. Hoskins
State Geologist

Preliminary Results from the Investigation of the Pymatuning Earthquake of September 25, 1998

John Armbruster[1], Henry Barton[2], Paul Bodin[3], Theodore Buckwalter[4], Jon Cox[5], Edward Cranswick[5], James Dewey[5], Gary Fleeger[6], Margaret Hopper[5], Stephen Horton[3], Donald Hoskins[6], Deborah Kilb[3], Mark Meremonte[5], Ann Metzger[3], Dennis Risser[7], Leonardo Seeber[1], Kaye Shedlock[5], Katherine Stanley[2], Mitchell Withers[3], Madeleine Zirbes[5]

INTRODUCTION. The Pymatuning earthquake occurred on Friday, September 25, 1998, at 19:52:52 Universal Coordinated Time (UTC), or 3:52:52 p.m. EDT, near Jamestown, Pa., at the southern end of the Pymatuning Reservoir, which straddles the Ohio-Pennsylvania border. The National Earthquake Information Center (NEIC) determined that the event had a magnitude of 5.2 mbLg (a magnitude scale used to measure the size of earthquakes that are regional distances away [100 to 1,000 km, or 60 to 600 mi]), an epicenter of 41.5°N latitude, 80.4°W longitude, and an estimated depth of 5 km (3 mi). One person was reported injured as a result of being thrown to the ground by the earthquake, and it caused minor damage to buildings and seriously disrupted many water wells in the Greenville-Jamestown, Pa., area. The earthquake was generally felt over an area of approximately 200,000 km^2 (77,230 mi^2) throughout northern Ohio, western Pennsylvania and New York, and much of southern Ontario, Canada (see map on back cover). It was also felt as far west as Illinois and Wisconsin, as far east as New Jersey, Connecticut, and the District of Columbia, and as far south as Kentucky and Virginia. During the aftershock field investigation that commenced

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within 12 hours of the main shock, a World Wide Web site, <*http://groundmotion.cr.usgs.gov/pym/pym.htm*>, was established from the field headquarters. The web site was used not only to transmit investigation results to the world in near real time but also to receive information from the local community as new earthquake effects were reported. As of March 1999, at least 11 aftershocks have occurred, the largest being a magnitude 2.3.

The largest recent previous earthquake in the region was the northeastern Ohio (Leroy) earthquake of magnitude 5.0 that occurred on January 31, 1986, about 65 km (40 mi) west-northwest of the Pymatuning shock. This event was also felt by many of those who felt the Pymatuning earthquake. Similar to most of the seismicity east of the Rocky Mountains, earthquakes in the region are probably shallow (5 to 10 km, or 3 to 6 mi), and Seeber and Armbruster (1993) hypothesized that the earthquakes occurred along preexisting zones of weakness in Precambrian rocks. Wegweiser and others (1998) suggested that seismicity in northwestern Pennsylvania may be associated with the northwest-trending “cross-strike discontinuities” that are recognized in Paleozoic rocks and may represent reactivation of faults in the Precambrian basement. Using structure-contour maps constructed on the tops of lower Paleozoic strata, Alexandrowicz and Cole (1999) found evidence of preexisting northwest-striking faults in the epicentral region of the Pymatuning shock. The Harvard focal mechanism for the Pymatuning earthquake (a method used to infer the slip and orientation of the fault that generated an earthquake) indicates thrust faulting on a northwest-striking plane, which is consistent with the regional northeast-southwest compressive stress regime observed in the area. Seeber and Armbruster (1993) plotted three prior earthquakes in the epicentral area having magnitudes greater than 3; two were instrumentally located near the Pymatuning earthquake, and the third event occurred 20 to 30 km (12 to 19 mi) to the northeast in 1852 (Figure 1).

CHASING THE EARTHQUAKE WITH PORTABLE SEISMOGRAPHS. Within 24 hours of the main shock, field parties from three institutions—the Center for Earthquake Research and Information (CERI), University of Memphis; the Lamont-Doherty Earth Observatory (LDEO), Columbia University; and the U.S. Geological Survey (USGS), Golden, Colo.—arrived in the epicentral area to deploy portable digital seismographs to record aftershocks. Earthquakes are usually followed by aftershock sequences—the largest aftershock usually being a magnitude less than the main shock—and the number of aftershocks per day decays exponentially with time. In general, the sooner record-

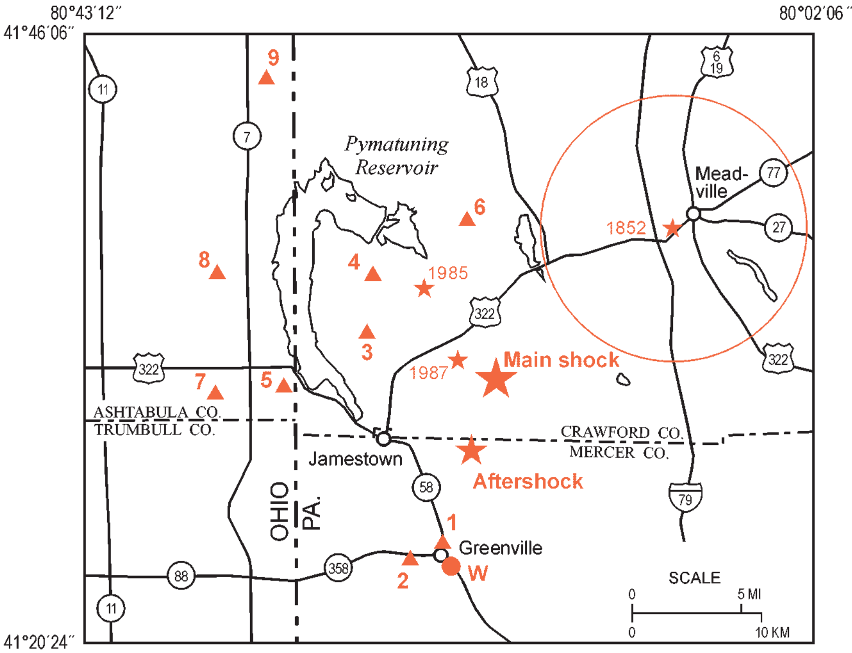

Figure 1. **Map of the epicentral area showing the Pymatuning main shock and first aftershock as colored stars, large and medium, respectively; two prior instrumentally recorded earthquakes in 1985 and 1987 as small colored stars; and a historic earthquake in 1852 as a small colored star surrounded by a circle that illustrates the uncertainty of the location based on felt reports. Of the 12 portable seismographs deployed, the nine that recorded the first aftershock are shown as colored, numbered triangles (the corresponding seismograms are shown in Figure 2); the other three are omitted. The colored dot labeled "W" is USGS well Mr–1364. Latitudes and longitudes are approximate.**

ing is begun, the greater the amount of information that can be obtained. Guided by the NEIC preliminary epicenter determination, the field party from CERI deployed its first seismograph at 2:00 a.m. Saturday morning. The LDEO field party began deploying seismographs on Saturday afternoon, and the USGS field party began deploying on Saturday evening. By Sunday, a total of 12 seismographs had been deployed, and we had set up a field headquarters at a motel near Greenville, Pa. (Figure 1).

Commonly, information about the causes of the main shock can be obtained from aftershock studies. Aftershocks that occur soon after the main shock tend to cluster near the fault plane that slipped during the main shock. Aftershocks too small to be detected by seismographs at regional distances can be recorded by a local seismograph array. These records are used to precisely locate the aftershocks, and particularly to determine their depths. The details of the location, orientation, and slip of the fault that caused the main shock can then be inferred from the pattern of aftershock locations. The nearest permanent seismograph station used in the NEIC location of the Pymatuning main shock was about 200 km (124 mi) away. The nearest seismograph that recorded the earthquake, approximately 50 km (31 mi) to the northeast, is operated by Brian Zimmerman of Edinboro University (who is also a member of the Public Seismic Network, found at <*http://psn.quake.net/*>), but the timing of this record is not sufficiently precise to be used in the earthquake-location determination.

The portable seismographs were generally deployed at the residences of private citizens, where electric power and security for the instruments were graciously provided. To minimize unwanted vibrations produced by the movements of daily life, the sensors were sited either within outbuildings or in backyards. With one exception, the seismographs stored recorded signals on disk drives and thus had to be visited to retrieve these data. The CERI group installed one of their seismographs at Thiel College in Greenville, where it was connected to the Internet and its data could be accessed remotely. We were thus able to use this station to monitor the local seismicity in near real time after the field parties departed the epicentral area on October 2, a week after arrival.

Unlike the 1986 northeastern Ohio earthquake that was followed by six aftershocks in the first 8 days (Nicholson and others, 1988), the first known Pymatuning aftershock was a magnitude 2.0 event that occurred on October 9 at 08:41 UTC (4:41 a.m. EDT), 2 weeks after the main shock. This aftershock has an epicenter of 41.477°N, 80.358°W (see Figure 1), a depth of 5.3 km (3.3 mi), and it was recorded at nine seismograph stations (Figure 2). There have been at least 10 additional aftershocks since the first aftershock, and they all have the same location within the uncertainties of hypocenter (focus) determination. The NEIC preliminary epicenter determination of the main shock was approximately 10 km (6 mi) west of the aftershocks, reflecting in part a mislocation due to the NEIC’s calculation of the epicenter using global-average travel-time tables. The main-shock epicenter used in this report has been relocated by using travel-time tables that are appropriate for eastern North America; it is still about 5 km (3 mi) from the aftershock epicenters, a discrepancy that likely is partly due to error in the relocated main-shock epicenter resulting from lack of close-in observations. Some of the discrepancy between the epicenter of the main shock and those of the aftershocks may also be due

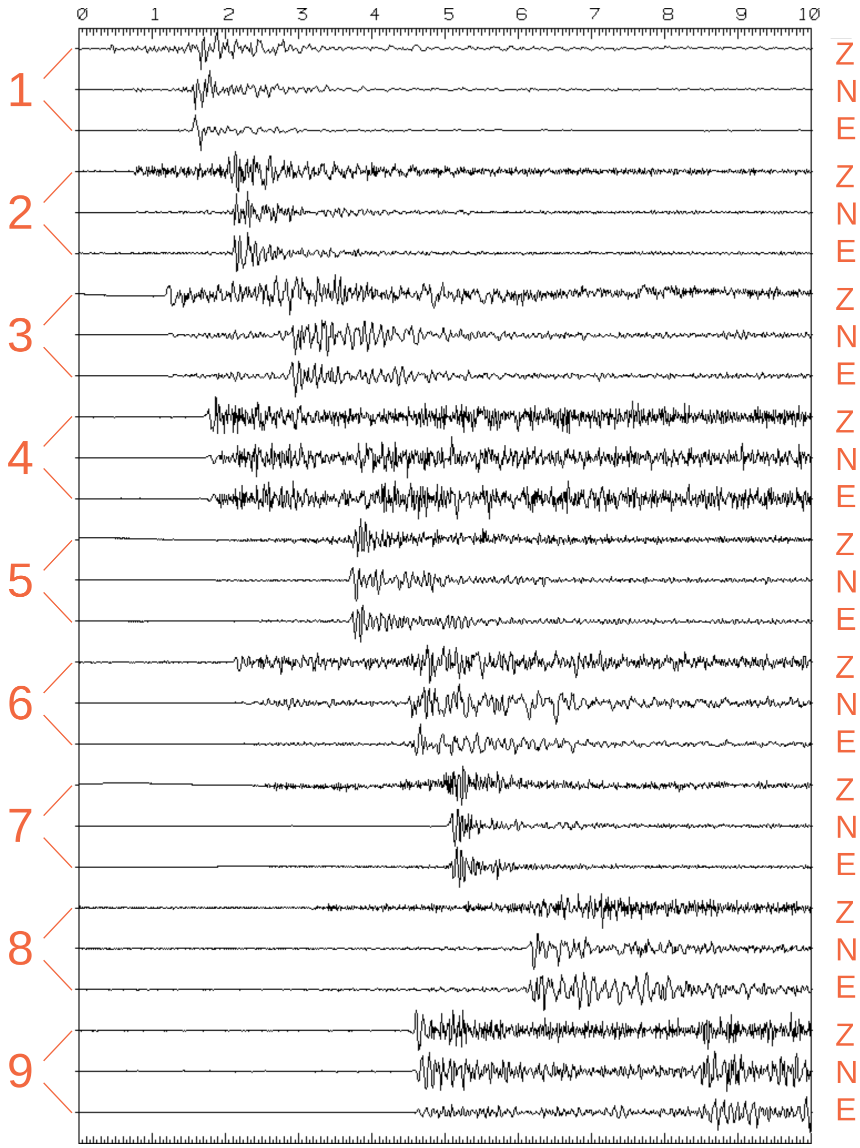

Figure 2. **Seismograms of the October 9 aftershock recorded by nine seismograph stations (the locations of the stations are shown in Figure 1). Ten seconds of the three components of ground velocity recorded at each station are displayed (Z, up-down; N, north-south; E, east-west), and the stations are ordered from top to bottom according to their increasing distances from the epicenter. The amplitudes of each trace are scaled to the peak amplitude of that trace, and they cannot be compared from trace to trace. Note that there is a relatively weak primary arrival (the P wave) on the Z component, followed by a stronger secondary arrival (the S wave) on the horizontal components (N and E).**

to the main-shock nucleation point occurring on a different part of the earthquake-causing rupture plane than the aftershocks, or to migration of the aftershock away from the main-shock source region with time, as is often observed in other main-shock/aftershock sequences.

Aftershock studies can also inform us about the effects of the main shock, that is, the intensities of ground shaking as indicated by damage to buildings and by human perceptions. Different sites exhibit variations of main-shock intensity that are often correlated with variations in the geologic characteristics of those sites. Similarly, aftershock records from those sites exhibit variations of amplitude and duration that can be used to corroborate the pattern of main-shock intensity and to investigate the mechanisms by which the corresponding geologic structures modify ground motions. Greenville and Jamestown, like other towns in the region, are built in valleys that are filled with as much as 100 m (328 ft) of glacial deposits.

An earthquake powerful enough to generate strong ground motions, unlike virtually any other natural or artificial phenomena, focuses the attention of the whole community almost instantaneously on the event. The World Wide Web, more than any other medium, allows members of that community to share the experience with each other. To inform people of the results of our investigation, and also—of equal importance—to solicit information about the earthquake from people who experienced it, we established a web site at our field headquarters. Our audience was the scientific community, the general public, and particularly the residents in the epicentral region who felt the earthquake or were aware of it from the local media coverage, because the residents could tell us their observations of the earthquake's effects.

INTENSITY OF THE EARTHQUAKE. An earthquake intensity is a number that represents the level of earthquake shaking in a community. The number is commonly represented as a Roman numeral, although on maps and in computer databases, Arabic numerals are used for conciseness and convenience. The intensity is assigned by consideration of the effects of the earthquake on people, on buildings and other human-made structures, on building contents, and on the landscape. The Modified Mercalli intensity scale is used in the United States to assign intensities, and it consists of descriptions of earthquake effects, ranging from I, "Not felt except by a very few under especially favorable circumstances," to XII, "Damage total." The maximum intensity of the Pymatuning earthquake was rated as VI, "Felt by all; many frightened and run outdoors. Persons made to move unsteadily. Broke [sic] dishes, glassware, in considerable quantity, also some windows. Fall of knickknacks, books, pictures. Overturned furniture in many instances. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight," for communities near the epicenter and for several additional communities in Pennsylvania and Ohio (Figure 3). Below are summaries of the intensity reports from two of those communities.

Greenville. A member of the Greenville Fire Department reported, "I was standing in a room on the second floor of my house when I felt the house shake violently for a short period of time. I heard a loud 'explosion-like' noise outside and some of my compact music disks fell off their storage shelf. I looked out the second floor window and saw all of my neighbors coming out of their homes. Most

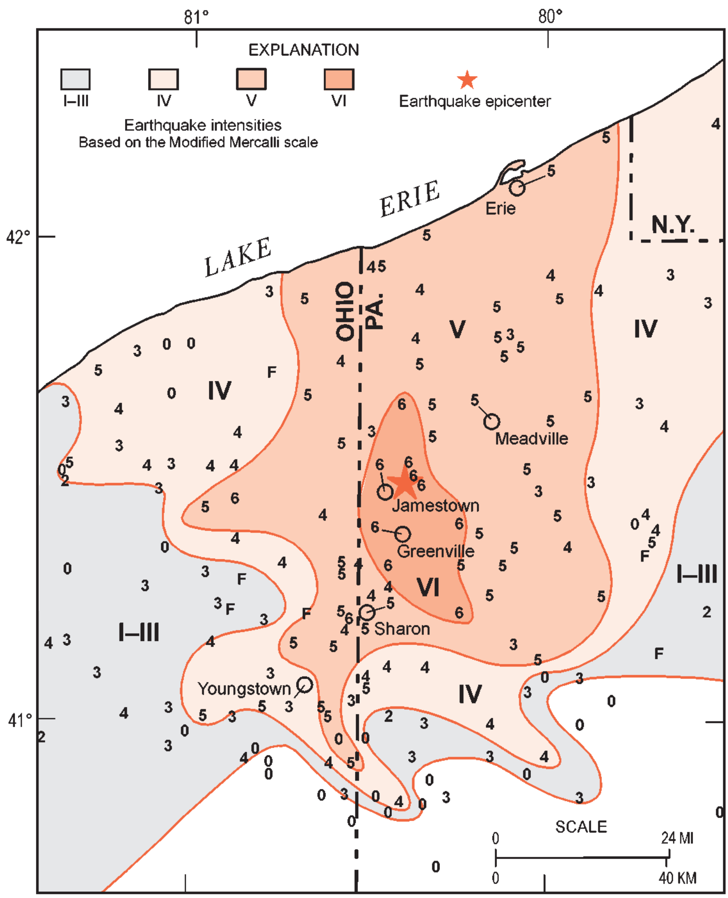

Figure 3. Large-scale map showing earthquake intensities in the epicentral area. Numbers indicate intensity at which earthquake was felt; 0, not felt; F, felt.

thought there was an explosion in the area. I drove to the fire station contemplating increased emergency activity due to whatever we had just experienced." The earthquake damaged a transformer at a factory, resulting in loss of power to the factory. A person was injured from being thrown to the ground. A few old chimneys cracked or lost bricks; exterior walls in some buildings sustained large cracks; some windows were cracked; in some houses, many items fell from shelves; items were shaken off store shelves; felt by all.

Jamestown. Ceiling tiles fell throughout the elementary school, and windows were broken in the building; an observer thought there would have been injuries in the school had the building been occupied at the time of the quake. Several old chimneys fell; concrete-block exterior walls sustained large cracks, and brick-veneer exterior walls sustained hairline cracks; interior walls sustained a few large cracks; plaster fell; many small objects overturned and fell; several dinnerware items and knickknacks broke; many items were shaken off store shelves; ten stores reported damage to inventory (see photograph on front cover); suspended objects swung violently; hanging pictures fell; many people ran out of buildings; felt by all.

Observations on damage and felt effects came from traditional sources used by the USGS for decades in its mapping of earthquake intensities and from submissions by electronic mail. The traditional sources of information are postal questionnaires, press reports, and reports from observers in the epicentral region. Geology students at Allegheny College in Meadville, Pa., conducted telephone and face-to-face interviews with people in selected communities affected by the earthquake and supplied approximately 100 survey reports.

The volume of e-mail observations far exceeded what had been collected previously for earthquakes occurring in the eastern United States. Overall, approximately 1,000 individual reports were submitted via the Internet. Most of these came from web sites at St. Louis University and the University of Memphis, and from e-mail collected at the Geological Survey of Canada. Some intensity observations were contributed by means of a form posted on a University of Nevada web site, and some observations were submitted to the USGS National Earthquake Information Center. Over 250 different communities are represented in the e-mail responses.

RESPONSE OF THE COMMUNITY. The Pymatuning earthquake caused much excitement in western Pennsylvania and eastern Ohio. Though this earthquake was relatively small (several events of this size happen each year in California), the fact that it occurred in an area that has very little seismic activity caused people to be very interested. Relative to other earthquakes of comparable size investigated by the USGS, the Pymatuning earthquake generated the most intense coverage by the local and regional media; for example, to do a story on the earthquake, a regional television station sent a news team in a helicopter that landed in the field behind our motel field headquarters. Even 2 months after the earthquake, stories relating to the aftereffects were still front-page news in the local media, and people were very interested in what results researchers found and were happy to complete intensity surveys.

The maximum Modified Mercalli intensity of VI assigned to the earthquake corresponds to minimal damage; however, any damage at all was a surprise to the residents. Few people in this area carry earthquake insurance (we have heard of only one person who actually had this insurance), and, therefore, any repairs were paid for entirely out-of-pocket. This became significant when water wells in the area began drying up within days of the event. As time has passed, there have been additional reports of new wells having to be dug, and a recent report of some wells in Ohio that have gone dry. The cost of most earthquakes is highly visible damage to buildings and other human-made structures, but the cost of the Pymatuning hydrologic effects is a hidden result of this earthquake.

HYDROLOGIC EFFECTS. Hydrologic changes related to the Pymatuning earthquake were reported by numerous residents of the Greenville-Jamestown area. The most serious change has been the loss of water at more than 100 household-supply wells not far from the earthquake epicenter. The maximum measured water-level decline was more than 30 m (100 ft). Other residents reported new flowing artesian wells, the formation of new springs, and changes in well-water quality (“black water and sulfur”). According to USGS hydrologists in Ohio, these hydrologic changes are nearly identical to those reported by nearby residents of northeastern Ohio after the earthquake there of similar magnitude in 1986.

Poth (1963) described shallow groundwater in the Mercer, Pa., 15-minute quadrangle (in southern Mercer County) as circulating in a series of “hydrologic islands.” The dissection of the bedrock surface of the Mercer quadrangle has resulted in ridges largely surrounded by valleys containing perennial streams. These ridges constitute the hydrologic islands. Poth’s description can be extended to northern Mercer County (see Figure 1). A shallow local groundwater-flow system operates within each hydrologic island and is hydrologically isolated from the local groundwater-flow systems in adjacent islands. Most recharge to these hydrologic islands discharges to the surrounding valleys; a small amount recharges to deeper flow systems.

The topographic ridge having the highest concentration of reported water-well changes is a textbook example of a hydrologic island. Most groundwater in this ridge is stored and transmitted via bedrock fractures and bedding-plane partings. Shallow wells on the highest points of the ridge went dry as soon as the morning after the earthquake. Deeper wells on the ridge and wells along the flanks of the ridges went dry in the weeks after the quake. Some of the first wells that went dry obtained good yields when deepened, but went dry again within a month.

Conversely, there were springs, wells, ponds, and streams that, either immediately after the earthquake or within several days, increased flow or began new discharges. These are all located on the lower slopes of the ridge and in the bordering stream valleys (the discharge areas). USGS observation well Mr–1364 in Greenville, located in a valley, recorded a 0.6-m (2-ft) rise in the groundwater level shortly after the earthquake (Figure 4). Some of the locations having increases in water level or flow returned to their pre-earthquake levels within two months, but most have not.

These hydrologic phenomena may be explained by the hypothesis that the earthquake created new fractures or opened old fractures through aquitards (low-permeability zones) beneath the upper aquifer(s). On the ridge-top recharge area, groundwater flow in the local flow system has a downward component. If the fractured-aquitard hypothesis is correct, the newly opened fractures increased the downward hydraulic conductivity through the aquitard, increasing the downward movement of groundwater. This would create a zone of water-table depression along the fracture(s). Shallow wells nearest the fracture(s) would have gone dry soon after the earthquake as the water table lowered. Later, as the water table continued to lower and the zone of depression spread, deeper wells on the ridge and wells along the flanks of the ridge would have started to go dry. Wells nearest the fracture(s) on the top of the ridge that went dry initially and were then deepened would have gone dry a second time as the water table continued to drop. A consequence of the increased downward movement of groundwater in the recharge area would have been an accompanying increase in discharge from new springs, flowing wells, and new wet areas (seeps) in the low-lying discharge area, and increased flow in the deeper flow systems as manifested by the

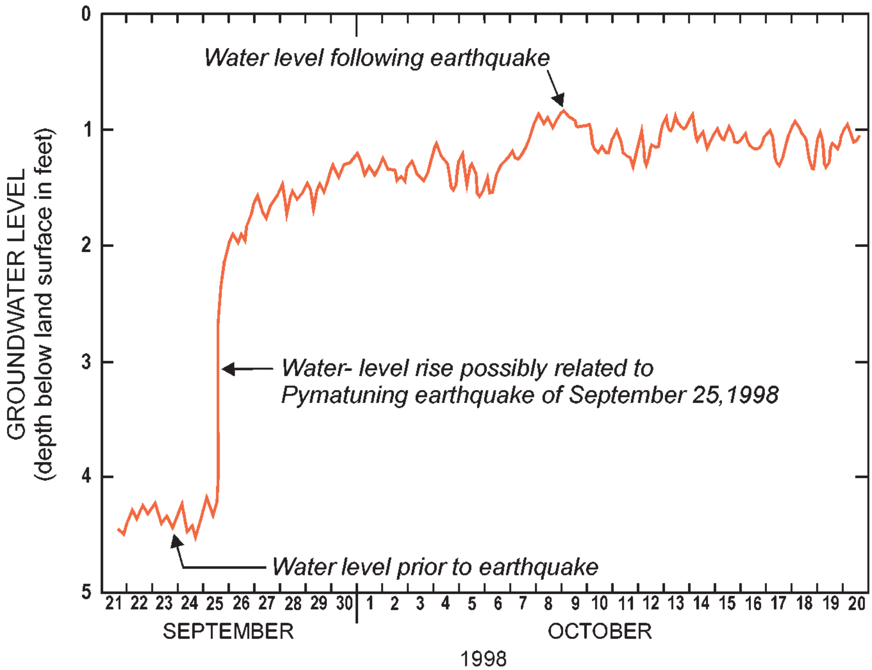

Figure 4. A 0.6-m (2-ft) rise in the groundwater level was recorded in USGS observation well Mr–1364 in Greenville on September 25.

water-level rise in Mr–1364 and by the presence of flowing wells in adjacent valleys. The local flow system does not yet appear to have reached a new equilibrium. These hydrologic changes currently are under investigation by the USGS in cooperation with the Pennsylvania Bureau of Topographic and Geologic Survey and Thiel College.

CONCLUSIONS. The Pymatuning earthquake jolted a community into an awareness of its relationship with the earth. The event may have been related to reactivation of "cross-strike discontinuities," whose presence is strongly manifested in the northwest-trending valleys that dissect the bedrock of the area. These valleys have historically been the loci of settlement, and today, as for most areas worldwide, the valleys contain higher population densities than the nearby ridges. The valleys are the sites of bounteous aquifers that supply the towns, but the valleys are also underlain by the greatest thickness of unconsolidated glacial deposits, which can amplify earthquake-generated ground motions that pose a hazard to the towns. Note in Figure 3 that the contours of earthquake intensity, that is, of increased shaking, exhibit a northwest trend. Conversely, the bedrock that underlies the less populated ridges between the valleys does not amplify the ground motions, but neither does it constitute a robust aquifer. The earthquake effects on the ridges were severe enough to damage the fragile aquifer, and many wells there went dry as a result. The fragility of the connection between the shallow aquifer and the deeper bedrock may perhaps be seen as a metaphor for our connection to Earth.

ACKNOWLEDGMENTS. We thank Mary Cajka (Geological Survey of Canada), Ron Cole (Allegheny College), Mike Hansen (Ohio Department of Natural Resources), and Melanie Whittington (St. Louis University) for contributing intensity observations collected by their institutions. We are grateful to many people for allowing us to install seismographs at their homes, including Ken Behner, the Cole family, Brenda Diehl, Pat Engstrom, Charles Floch, Robert and Dorothy Hopp, Paul Krueger, Paul Mechling, Tom Patton, Robert Riley, Robert Shetler, Liz and Ray Stuyvesant, Gary Tabor, Sandra Teter, Tim Tyler, William Webster, Vera and Fred Williams, and Robert Zahigian. The staff of Cianci's Motel in Greenville provided us with an excellent field headquarters and were particularly gracious in dealing with our various special requests and the flood of telephone calls, media, and other visitors who arrived in our wake. We also thank Thiel College computer services, especially the extensive help from Greg Booty. Marianne Calenda from Thiel College mitigated many problems as did many helpful Security folks at the college. Regis Shawkey of the Golden Dawn Supermarket kindly provided us with photographs of earthquake damage. Larry Davis of A–1 PC Computer Shops in Greenville generously loaned us a digital camera that allowed us to put photographs directly on our web site in the field. We thank the personnel of Pymatuning State Park in Pennsylvania, particularly Pete Houghton and Dennis Mihoci, for assistance and maps. James Thompson, Director of the Mercer County Department of Public Safety, alerted us to the water-well problem. The Ohio State Geologist, Thomas Berg (the geologist from both sides of the border), promptly provided us with with information in the field. We are grateful to the USGS state representatives of Pennsylvania, Gary Paulachok, and of Ohio, Steven Hindall and Rod Sheetz, for their help. Rob Wesson and Russ Wheeler of the USGS in Golden, Colo., gave very prompt and effective reviews of this article. The local and regional media were very cooperative and helped connect the field investigators with the public. Finally, we wish to thank the many unnamed people whose felt reports and other observations of earthquake effects—submitted via voice, mail, or Internet—were essential to this investigation; and we are particularly grateful to the residents of the epicentral area who welcomed us and made us feel at home.

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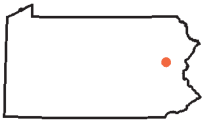
NEW RELEASES

Rocks and Ruins of the "Upper Grand"



A new open-file report on the geology and history of the Lehigh Gorge area has been released by the Bureau of Topographic and Geologic Survey. **Open-File Report 98–03, Rocks and Ruins of the "Upper Grand"—An Illustrated Trail Guide to the Geology and Historical Archeology of Lehigh Gorge State Park, Northeastern Pennsylvania,** was written by staff geologist Jon D. Inners.

The 62-page illustrated trail guide includes a road log and site descriptions of the geology and historical archeology of Lehigh Gorge State Park.

The "Upper Grand Section" of the Lehigh Canal contained 20 dams and 29 "high-lift" locks. It was in operation between 1829 and 1862. After abandonment of the canal, construction of railroads began. Now a rail trail through the Lehigh Gorge follows one of the former railroad grades.

"The gorge has a very rich canal and railroad history," said Inners. "I hope this report will help expose more people to the geology (rocks) and industrial archeology (ruins) of the Lehigh Gorge area."

Lehigh Gorge, located on the boundary between Carbon and

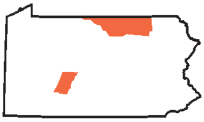
Lock no. 22 at Mud Run, one of the best-preserved locks of the "Upper Grand."

Luzerne Counties, exposes cliffs of red and gray sandstone that ranges in age from 375 to 320 million years old.

Six plates showing the bedrock geology, fold axes, glacial features, locks and dams of the "Upper Grand," railroads, and a map of the historical Lehigh Tannery are also included in the report.

Copies of Open-File Report 98–03 can be purchased for **$3.00** **plus $0.18 sales tax** for Pennsylvania residents from Open-File Sales, Bureau of Topographic and Geologic Survey, P. O. Box 8453, Harrisburg, PA 17105–8453. Prepayment is required; please make checks payable to *Commonwealth of Pennsylvania.* The report may be examined in the Bureau's library at 1500 North Third Street, Harrisburg, and in the Pittsburgh office of the Bureau at 500 Waterfront Drive.

Two New Groundwater Resource Reports Available



The Bureau of Topographic and Geologic Survey recently published **Water Resource Report 67, Groundwater Resources of Cambria County, Pennsylvania,** and **Water Resource Report 68, Hydrogeology and Groundwater Quality of the Glaciated Valleys of Bradford, Tioga, and Potter Counties, Pennsylvania.**

Water Resource Report 67, by staff geologist Thomas A. McElroy, consists of a 49-page text accompanied by a full-color, 1:50,000-scale geologic map of Cambria County showing the locations of selected wells and springs. The report includes descriptions of the water-bearing properties of 10 stratigraphic units, chemical analyses of groundwater from 5 springs and 70 wells, chemical analyses of 27 samples of acid mine drainage, hydrogeologic and well-construction data for 230 wells, and a comparison of the hydrologic cycle in a strip-mined and an unmined basin.

Water Resource Report 68 was a cooperative project between the Bureau of Topographic and Geologic Survey and the U.S. Geological Survey (USGS). It was written by John H. Williams of the USGS, Larry E. Taylor of Moody and Associates, Inc., and Dennis J. Low of the USGS. At the time the report was being prepared, Taylor was a geologist with the Bureau. The report consists of an 89-page text accompanied by a two-color, 1:100,000-scale surficial geologic map (on two plates) of the major glaciated valleys in Bradford, Tioga, and Potter Counties. The map shows locations of wells, test holes, and data-collection sites discussed in the text, and the locations of numerous hydrogeologic cross sections included in the margins of the plates. In the text, the authors describe the hydrogeologic setting and hydrogeochemical system in valleys north of the late Wisconsinan glacial border in north-central Pennsylvania. Hydrogeologic and well-construction data from approximately 900 wells and test holes are presented in tabular form in the back of the report. In their study, the authors supplemented these data with data obtained through geophysical surveys and well logs, groundwater-level monitoring, infiltration studies, and chemical analyses of groundwater from more than 200 selected wells.

The reports may be purchased from the State Book Store, 1825 Stanley Drive, Harrisburg, PA 17105–1365. Water Resource Report 67 is **$12.66 plus $0.76 state sales tax,** and Water Resource Report 68 is **$15.47 plus $0.93 state sales tax.** Sales tax applies to Pennsylvania residents only. All orders must be prepaid; please make checks payable to *Commonwealth of Pennsylvania.*

The geologic maps for both reports were printed before the books and were made available to the public at a reduced publication cost (see announcement in *Pennsylvania Geology,* v. 26, no. 3/4, p. 13). People who purchased these maps previously may obtain the accompanying books directly from the Bureau. If interested, send a check payable to *Commonwealth of Pennsylvania* for the balance in cost, **$4.46 (plus $0.27 state sales tax, if applicable)** for Water Resource Report 67, and **$5.87 (plus $0.35 state sales tax, if applicable)** for Water Resource Report 68, to the Pennsylvania Geological Survey, P. O. Box 8453, Harrisburg, PA 17105–8453.

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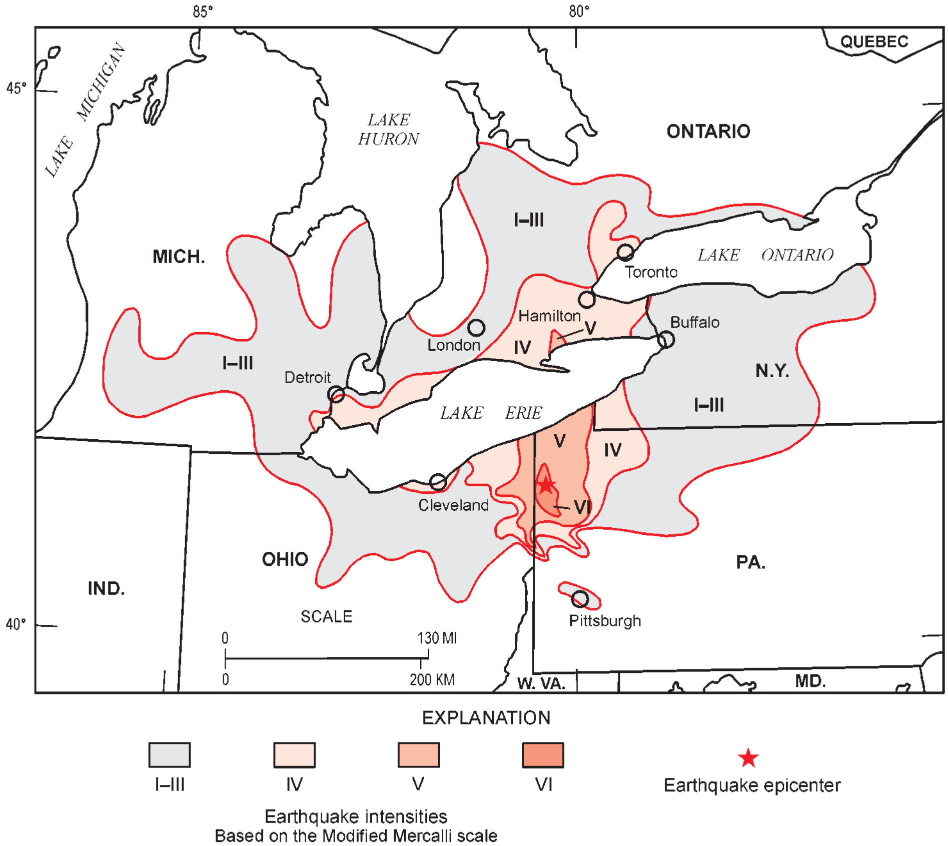
IN COOPERATION WITH THE U.S. GEOLOGICAL SURVEY

TOPOGRAPHIC MAPPING
GROUNDWATER-RESOURCE MAPPING

PYMATUNING EARTHQUAKE INTENSITIES

The map shows earthquake intensities throughout the region in which the Pymatuning earthquake of September 25, 1998, was generally felt. (See article on page 2.)



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