PENNSYLVANIA GEOLOGY

THE PENNSYLVANIA GEOLOGICAL SURVEY VOL. 18/2

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ON THE COVER: Sinkhole in Macungie Borough, Lehigh County. The sinkhole opened on June 23, 1986, and was approximately 75 feet in diameter and 35 feet in depth. See article on page 11. (Photograph taken June 24, 1986, by W. E. Kochanov.)

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Editor, Donald M. Hoskins
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There Are No Magic Bullets

In the attempts we make in solving everyday geologic problems that arise from our interaction with our environment, we must continually remind ourselves that there are no easy answers, no "magic bullets," so to speak, to end these problems.

Two problems, having geologic origins, that face Pennsylvanians today are discussed in this issue. Both are the result of natural earth processes that have operated over eons, those grand divisions of geologic time that have transpired since the beginning of our planet.

The dissolution of our carbonate rocks to form sinkholes and the natural decay of uranium to form radon both have operated over very long periods of time. There is no way to stop such natural processes, no "magic bullet" to halt their progress.

Instead we must learn to understand these earth processes and adjust our activities to avoid their deleterious consequences. We need to know that we are part of our planet—our earth—our Commonwealth's environment—and by so knowing recognize and respect the natural processes. With appreciation of geologic time and the inexorable dynamic action of the earth's natural courses, we can better avoid problems that are part of our state's geology.

Donald M Hoskins

State Geologist

GEOLOGY IN THE PUBLIC ARENA

by Elisabeth Guerry Newton
Division of Geology and Mineral Resources
U.S. Bureau of Land Management

"Civilization exists by geological consent. . .subject to change without notice," according to Will Durant. It has been said that for every dollar that society is willing to invest in the application of the geosciences to the solution of its problems, the return to the public benefit is one hundred fold. It is within the public arena that this benefit is most evident.

Although our way of life has become more demanding upon our natural resources and our cultural and social environments have created population concentrations that cannot avoid geologically unsuitable habitats, it is positive to note that our decision makers and the public are becoming increasingly aware of the limits and constraints that natural conditions impose upon man's utilization of the earth's resources.

It is not so positive, however, to note that the requisite awareness of problems that are subject to solution through geological and engineering expertise often only occurs after a destructive episode, and is commonly accompanied by emotionalism and unrealistic interpretation of a worst ultimate outcome. Such was the case of the 1969 oil spill in the Santa Barbara Channel, California. There are equally frequent episodes, unfortunately, where, despite mounting evidence that a severe adverse situation is developing and life and property are being imperiled, a situation is ignored until tragedy occurs. This has been the case where floodplains have been developed, unstable terranes disturbed, water resources misused or mismanaged, or hazardous materials disposed of without proper regard for repository conditions.

Solutions and accommodations to issues such as these are usually addressed most effectively within the public sector. It is within this public arena that geology, and engineering geology in particular, can perform vital service by offering advice and counsel to a concerned public, and to policy and decision makers. It is essential that decisions affecting our natural resources, our health and welfare, and our national security be made with *proper consideration of,* and *respect for,* the relationship between such activities and natural geological conditions that must be accommodated.

Excerpt from the Keynote Address, "Symposium on Engineering Geology in Public Policy," Annual Meeting of the Geological Society of America, November 10, 1986, San Antonio, Texas.

Radon: A Profound Case

by R. C. Smith, II, Pennsylvania Geological Survey
M. A. Reilly, Pennsylvania Bureau of Radiation Protection
A. W. Rose, The Pennsylvania State University
J. H. Barnes, Pennsylvania Geological Survey
S. W. Berkheiser, Jr., Pennsylvania Geological Survey

In late December 1984, the world's most severe indoor radon problem to date was discovered in a house in Colebrookdale Township, Berks County, in the Reading Prong physiographic province of Pennsylvania. Radon is a naturally occurring, colorless, odorless, inert, but radioactive gas, with a half-life of 3.8 days. It is a decay product of the most abundant naturally occurring isotope of uranium, U^{238}, and has radium as its immediate radioactive parent. Uranium and radon are found nearly everywhere in very small concentrations. Radon and its daughter products decay by the emission of alpha particles, essentially helium nuclei (two protons and two neutrons) carrying a charge of +2. Because of their large mass and charge, alpha particles travel only a short distance through body tissue, and have the capability of causing extensive damage when they encounter living tissue. The risk of lung cancer is understood to be proportional to the amount of exposure to radon decay products in air.

Radon is measured in radioactivity units called picocuries (pCi). One picocurie of radon is approximately the quantity that would yield the disintegration of two atoms per minute. The U. S. Environmental Protection Agency has suggested that the concentration of radon in the air of residential buildings should not exceed 4 picocuries of radon per liter (quart) of air. The house in Colebrookdale Township, the "Index House," was found to contain 2,500 pCi Rn/L (picocuries of radon per liter) for sustained periods.

How bad is that? Different individuals comprehend this in different ways. It is over 40 times the amount of radon allowed in active portions of U.S. uranium mines for a 40-hour work week. The annual radiation dose to the lungs continuously exposed to the Index House concentration is 8,700 Rem, or about 1 Rem per hour. For comparison, the worst exposure that could have theoretically been sustained by an individual during the March 1979 accident at the Three Mile Island nuclear power plant, had he stood on the edge of the property for the entire 11-day event, would have been only 83 milliRem, or 0.083 Rem (Battist and others, 1979). Thus, living in the Index House environment could be compared to being exposed to a TMI-like event 105,000 times each year! Living in the Index House could also be compared to having a chest X-ray every 20 seconds around the clock, or to smoking 136 packs of cigarettes per day, about one cigarette every 30 seconds. Using generally accepted risk models derived from a variety of independent sources, continuous exposure would result in a 13 percent lifetime chance of contracting lung cancer for each year of occupancy. Such comparisons serve to suggest the severity of the problem. Scientists and technicians can perhaps best comprehend the magnitude of the problem from the fact that air samples from the Index House yielded such high count rates that intrinsic germanium detectors could not keep pace, that opening the windows in the basement cut the gamma flux from 150 down to 60 μR/hr (microroentgens per hour) in that area (probably about 110 μR/hr cloud shine and 40 μR/hr flux through the floor and walls), or that visitors' clothing picked up a 70-μR/hr short-lived radon daughter contamination. Basement cracks yielded up to 250 pCi of radon per foot of crack per second!

What caused it? High indoor radon concentrations depend primarily on the amount of parent uranium in the bedrock and soil around a house, the efficiency with which the minerals involved emanate the radon that is produced, the porosity and permeability of bedrock and soil, house construction, life style (opening and closing of doors and windows), and especially "chimney effects." In the case of the Index House, several deleterious factors combined to yield a "worst case" situation.

A composite bedrock sample was collected from a 26-foot diagonal across the basement after the basement floor was removed (Figure 1). This sample yielded 50 ppm (parts per million) uranium (Table 1). If radiometric equilibrium existed, this would yield 17.5 pCi of radon per gram of rock. However, the average radon/uranium emanation efficiency is only about 20 percent (Table 1), and the rock actually releases only about 3.5 pCi/g (picocuries per gram). Calculations based on this and the fact that air in the Index House contained 1.6 mCi (millicuries) of radon, suggest that at least the first 30 feet of bedrock surrounding the basement was functioning as a radon source. However, a smaller volume of source rock is required if rock that has had less of its uranium leached is present at shallow depths. The mechanism whereby radon is concentrated from large volumes of rock into a house remains unclear. A water table no more than 47 feet below the surface suggests that upwelling groundwater may have been playing a deleterious role, even though the well water contains only about 20,000 pCi Rn/L, an amount exceeded by a factor of 12 elsewhere in the Reading Prong (Rumbaugh, 1983).

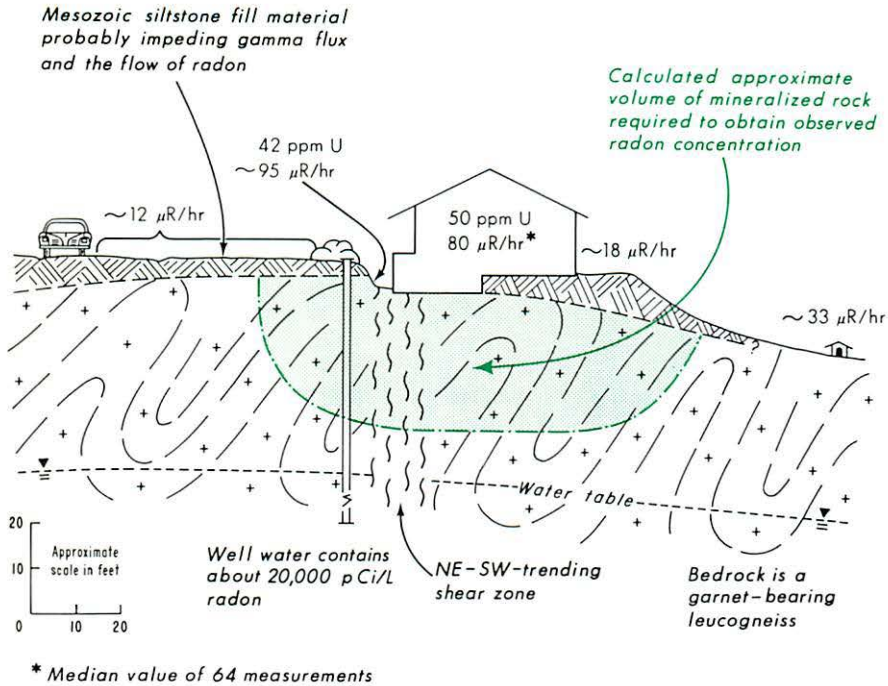


Figure 1. Generalized cross section of the "Index House" site as viewed from the east, Colebrookdale Township, Berks County, Pennsylvania. The trench in front of the house was only temporary. The 80 μR/hr was measured in contact with bedrock beneath the lowest level of the house when it was fully ventilated. The width of the shear zone at this location is unknown.

Unlike the majority of the uranium occurrences in the Reading Prong, this occurrence is located in a faulted shear zone. It is probably similar to the one reported by Smith (1978) on the northwest side of Oley Valley, which was estimated to contain 58 ppm uranium. Neither area is particularly uranium-rich compared with other, anomalously radioactive Reading Prong "granitic" occurrences, which have a median uranium content of 81 ppm.

X-ray diffraction examination of the bedrock composite sample suggests that the source rock consists of major amounts of quartz, plagioclase, and a potash feldspar, and trace chlorite. Thin-section examination reveals that (1) the quartz, in particular, is highly sheared; (2) the feldspars are perthitic microcline and sericitized plagioclase; (3) fractured pink garnet is a minor component; (4) epidote occurs as radiating aggregates in fractures in the rock

Table 1. *Analyses of rock samples (in parts per million) from the Index House shear zone, Colebrookdale Township, Berks County. See Figure 1 for relative locations.*

	Uranium Fluorimetric (Commercial)	Uranium Delayed neutron activation (A. W. Rose)	Thorium Delayed neutron activation (A. W. Rose)	Percent emanation efficiency from radon/uranium (A. W. Rose)
Twenty-six-foot diagonal across basement floor*	50	49	33	12
Point source composite outside southeast foundation	42	44	47	14
Thirty-foot horizontal composite outside south foundation	28	30	47	12
Twenty-foot horizontal composite outside west foundation	36	35	58	36

*Commercial analyses of this deepest and freshest sample yielded 6.0 percent potassium, 55 ppm uranium, 81 ppm thorium, and 0.40 ppm europium. For comparison, the median contents of 47 widely separated "granitic" uranium occurrences in the Reading Prong are 81 ppm uranium and 161 ppm thorium.

matrix and with chlorite in garnet; (5) monazite occurs as subhedral grains with orange alteration (radiation damage?) rims; and (6) zircon is present as tiny euhedral, zoned grains. Fractions of increasing magnetic susceptibilities, prepared from a panned heavy-mineral concentrate, yielded minor amounts of ilmenite; abundant dark-orangish-red garnet; minor, partly altered tan monazite; and trace lustrous zircons with rounded terminations (many having brown cores and milky rims). Neither magnetite nor discrete uranium minerals were observed.

Semiquantitative trace-element analyses of the bedrock composite suggest a normal trace-element assemblage for a granitic rock, except for an observed lead content of about 100 ppm, which is high. The possibility exists that an appreciable fraction of the lead may be radiogenic. If 80 ppm of this lead is radiogenic and the occurrence formed near the end of the Grenville orogeny (approximately 1 billion years ago), then the unweathered rock could have contained on the order of 600 ppm uranium.

With research funding supplied by the Philadelphia Electric Company, ARIX Corporation supervised $32,670.81 worth of remedial construction and reduced the radon content of the Index House by a factor of over 1,000 and the gamma radiation levels from 28 to 13 μR/hr. The Index House is now safe. Obviously, had the risk from nature's radiation problem been identified and understood earlier, the house would not have been built as it was. Preconstruction caution in suspect terrain and private radon testing in the southeastern quarter of Pennsylvania are encouraged.

REFERENCES

Battist, Lewis, Buchanan, John, Congel, Frank, and others (1979), *Population dose and health impact of the accident at the Three Mile Island nuclear station,* Ad Hoc Population Dose Assessment Group of Nuclear Regulatory Commission, U.S. Department of Health, Education, and Welfare, and U.S. Environmental Protection Agency, 7 p. summary.

Rumbaugh, J. O., III (1983), *Effect of fracture permeability on radon-222 concentration on ground water of the Reading Prong, Pennsylvania,* University Park, Pennsylvania State University, M.S. thesis, 111 p.

Smith, R. C., II (1978), *Uranium near Oley, Berks County,* Pennsylvania Geology, v. 9, no. 4, p. 29-31.

NEW SURVEY PUBLICATIONS

THE NEW, REVISED STRATIGRAPHIC CORRELATION CHART OF PENNSYLVANIA

Pennsylvania Geological Survey General Geology Report 75 has been reprinted *and includes more than 80 revisions of varying degrees*. The **Stratigraphic Correlation Chart of Pennsylvania,** authored by T. M. Berg, M. K. McInerney, J. H. Way, and D. B. MacLachlan, has been one of the Survey's best sellers and has been used by a wide audience. When the chart was published in 1983, it was the first time that all of the stratigraphic names of groups, formations, members, and beds were ever assembled into one large diagram for the whole Commonwealth. The stratigraphic units of 15 geologically distinct areas in Pennsylvania are arranged in 15 vertical columns according to their age and vertical sequence as they occur in the field or in drill holes. The revisions to the chart, including the addition of some new names, occur mainly in the Quaternary, Lower Mississippian, Upper Devonian, Lower Silurian, and Lower and Middle Ordovician. Some revisions are simple corrections of misspellings in the original printing. Of special interest are the revision of the Middle Devonian (Tioga) and Ordovician ash-bed zones, and the addition of the Kalkberg, Belpre, and Center Hill ash-bed zones. The chart is available from the State Book Store, P. O. Box 1365, Harrisburg, PA 17105. The price is $5.40 (plus 32¢ tax for Pennsylvania residents). Enclose a check payable to *Commonwealth of Pennsylvania*.

NONFUEL-MINERAL PRODUCTION SHOWS INCREASE

The value of nonfuel-mineral production in Pennsylvania was $708.4 million in 1984, nearing the all-time high of $721.7 million in 1979. These and other facts about the production of nonfuel minerals in Pennsylvania are available free in Information Circular 95, **The Mineral Industry of Pennsylvania in 1984,** a newly released publication of the Pennsylvania Geological Survey. The report, written by L. J. Prosser, Jr., A. A. Socolow, and S. W. Berkheiser, Jr., is reprinted from *Minerals Yearbook 1984* by the U.S. Bureau of Mines. To obtain a copy of the publication, write to the Pennsylvania Geological Survey, Department of Environmental Resources, P. O. Box 2357, Harrisburg, PA 17120. Teachers interested in using the booklet in course work may order it in bulk quantity.

NEW OPEN-FILE REPORTS

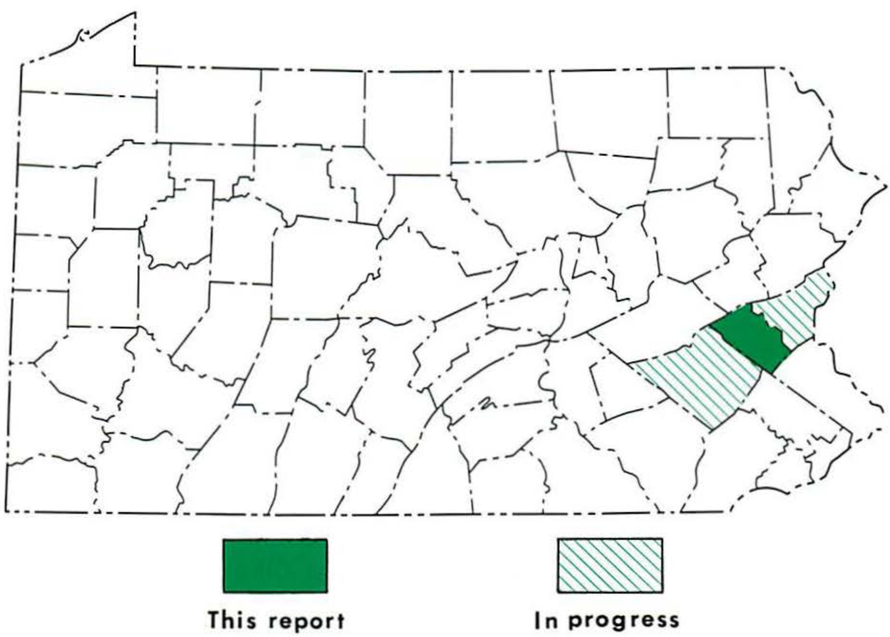
SINKHOLES IN LEHIGH COUNTY

The Pennsylvania Geological Survey has recently released Open-File Report 87-01, **Sinkholes and Related Karst Features of Lehigh County, Pennsylvania**. The report, compiled by staff geologist W. E. Kochanov, is the first in a series dealing with sinkhole occurrence and distribution throughout all of the limestone regions of Pennsylvania.

The report consists of six 7½-minute topographic quadrangle maps (scale 1:24,000) and a brief text. The maps depict known sinkhole occurrences, contacts of carbonate bedrock formations, structural data, past and present surface-mine locations, caves, and other karst-related features having surface expression. The text contains a brief discussion of the methods used in compiling the report, definitions of some basic terms pertaining to karst geology, and a list of references on the carbonate geology of Lehigh County.

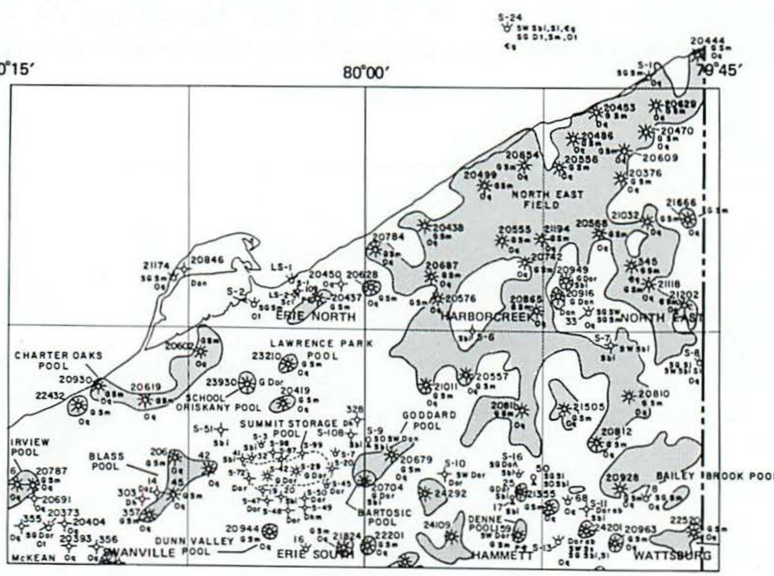
Concurrent with this report, a comprehensive computer data base concerning sinkholes in Pennsylvania is being developed at the Survey. Mapped sinkhole locations and physical data pertaining to specific sinkholes in Lehigh County have been entered into the data base by county, township, quadrangle (7½-minute), and coordinates (latitude and longitude). It will be continuously updated and utilized in answering requests for information on sinkholes in Lehigh County and eventually throughout the Commonwealth.

The Lehigh County open-file report can be examined at the offices of the Pennsylvania Geological Survey, 9th Floor, Executive House, 101 South Second Street, Harrisburg, or copies of the report can be purchased by mail order at the prepaid copying and shipping cost of $10.00 from the Pennsylvania Geological Survey, Department of Environmental Resources, P. O. Box 2357, Harrisburg, PA 17120. Checks should be made payable to *Commonwealth of Pennsylvania*.



REVISED MAP OF DEEP WELLS AVAILABLE

A revised and updated version of **Deep Well Oil and Gas Exploration and Development in Pennsylvania,** Open-File Report 2 of the Pennsylvania Geological Survey, has been completed and is now available as an ozalid (blueline or blackline) print to interested parties. The report, which was last updated in 1982, consists of a map in two sheets at a scale of 1:250,000, compiled and drafted by L. J. Balogh. The map shows the locations of several thousand deep wells (wells that penetrate the top of the Middle Devonian Tully Limestone or its equivalent) in Pennsylvania. All deep wells outside established fields are shown. Only selected wells within developed areas are shown, however, because of space limitations at this scale. All wells are identified by permit number (or Survey file number for wells drilled before permitting), and information is provided regarding formation at total depth, shows of oil, gas, and water, and producing formations. There is a new feature on this revision: the fields and pools, many of which are named on the map, are highlighted with a stipple pattern that makes it far easier to distinguish developed areas from potential exploratory areas (see the example printed below).



Details for ordering Open-File Report 2 can be obtained by contacting the Pennsylvania Geological Survey, Oil and Gas Geology Division, 7th Floor, Highland Building, 121 South Highland Avenue, Pittsburgh, PA 15206-3988, telephone 412-645-7057.

AERIAL PHOTOGRAPHS PROVE SINKHOLE ORIGIN

by William E. Kochanov
Pennsylvania Geological Survey

On June 23, 1986, a large sinkhole opened suddenly in Macungie Borough, Lehigh County (Figure 1). The sinkhole, which measured approximately 75 feet in diameter and 35 feet in depth, occurred in a street separating an apartment and a townhouse complex (Figure 2). Continued sloughing of the sides of the sinkhole and radiating tension cracks, which encroached on an adjoining parking lot, prompted the evacuation of 20 homes and apartments. Fortunately, there were no injuries to residents as a result of the collapse, but damage to the street and buried utility lines was extensive.

The Pennsylvania Geological Survey became involved with the Macungie sinkhole through a request to the Department of Environmental Resources from the borough manager. The Environmental Geology Division of the Survey worked in a cooperative effort with borough officials, consultants, and building contractors by supplying background information on the carbonate geology of the area and investigating the recent history of the site in order to determine an effective and feasible solution to the problem.

Figure 1. Sinkhole location in the Allentown West 7½-minute quadrangle.

The collapse occurred in colluvial and recent fill materials overlying the Middle Cambrian Leithsville Formation. The Leithsville is a dark-gray to medium-gray, massive dolomite containing thin calcareous shale and sandy dolomite interbeds. The surficial colluvial materials in the area of the sinkhole consist largely of granitic gneiss and quartzitic sandstone fragments, derived from the hills to the south, in a residual soil matrix.

The history behind this occurrence is interesting and well documented by a sequence of aerial photographs.

Figure 2. Sinkhole in Macungie Borough as it appeared on June 24, 1986.

Interviews with longtime residents of the area revealed that a pond had existed in approximately the same location as the sinkhole. It was also suggested that the sinkhole could have been a reopening of a previously existing iron mine. Information on past mining operations obtained from the Mineral Resources Division of the Pennsylvania Geological Survey and from the U.S. Bureau of Mines showed that no mining had taken place in the area of the collapse.

To determine the origin of the collapse, aerial photographs were used as an aid in establishing the history of the site. The Pennsylvania Geological Survey library has sequential aerial photographic coverage of the entire state for the past 40 years. Examination of the site of the Macungie sinkhole on a 1947 aerial photograph (Figure 3a) shows a roughly circular water-filled pond approximately 200 feet in diameter. Examination of a photograph taken in 1958 (Figure 3b) shows a deep hole that no longer contained any water. At the northern end of the hole, several dark circles are apparent, and from this it was deduced that there was at least one, and perhaps three, openings that drained the pond sometime between 1947 and 1958. Further photographic evidence from 1964 and 1971 shows that the hole had been filled and crops planted over it (Figure 3c and 3d). A stereo zoom transfer scope, which allows one to view a pair of stereo air photographs and to transpose that image onto a base map, was used to verify that the "pond" and the recent sinkhole were indeed at the same location.

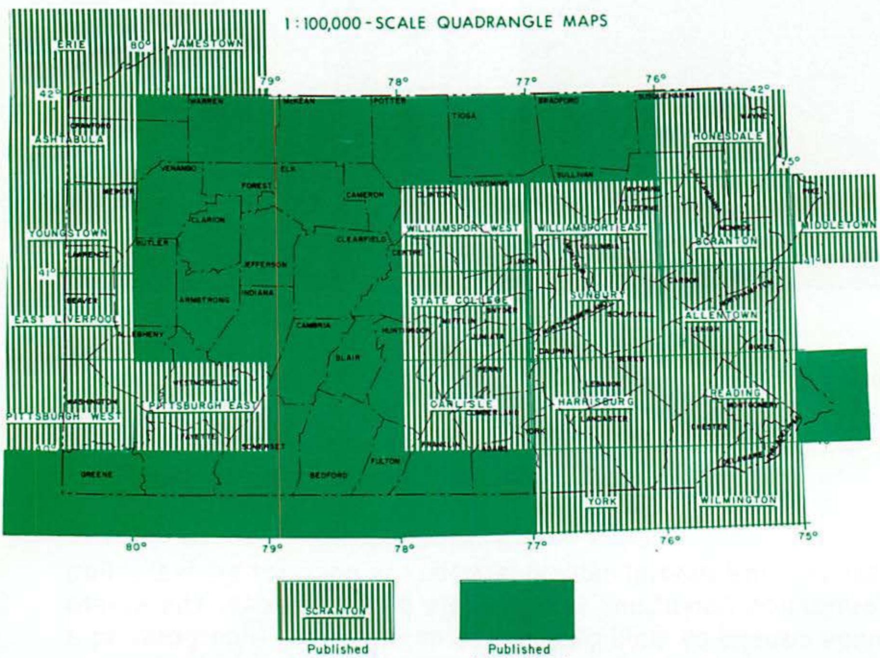
Repair of the sinkhole occurred over a period of more than 3 months and cost the borough over $400,000.

Figure 3. Sequence of aerial photographs showing the evolution of the Macungie sinkhole: (a) 1947, (b) 1958, (c) 1964, and (d) 1971. All photographs are from the U.S. Department of Agriculture. Development in the area occurred after 1971.

This account dramatically illustrates the need for an evaluation of foundation conditions in carbonate bedrock areas. The severe damage caused by sinkholes can be minimized by incorporating a thorough subsurface investigation in the planning stages of a project in an area that is considered to be prone to sinkhole development. In the case of Macungie Borough, it would have been to the benefit of the developers of the area or their engineers to have examined the various series of aerial photographs, available to the public, prior to the onset of any construction activity.

U.S. GEOLOGICAL SURVEY METRIC TOPOGRAPHIC MAPS

In April 1984, a series of topographic maps at a scale of 1:100,000 (1 centimeter on the map equals 1 kilometer, or about 1.6 miles, on the ground), was announced in *Pennsylvania Geology*. The maps are multicolored, and show political boundaries, highways, man-made structures, cultural features, and topographic contours (interval 20 meters). In addition to providing much of the detail shown on larger maps, the 1:100,000-scale maps cover enough geographic area to be useful as regional base maps.



Thirty-four maps in this series have been completed for Pennsylvania. Fourteen of the maps are in a topographic format and 20 in a planimetric format. Eventually all of the maps in this series will depict topography. Please refer to the index map for coverage information.

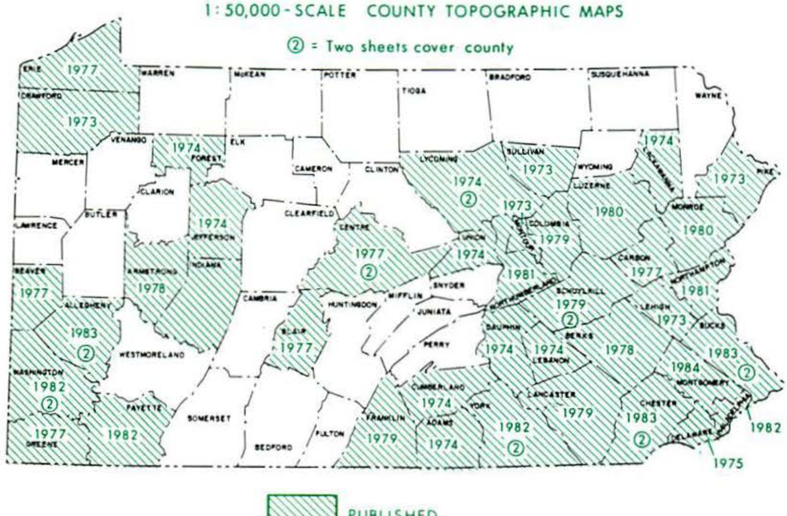
Published maps are available for $4.00 each from the U.S. Geological Survey, Map Distribution, Box 25286, Federal Center, Denver, CO 80225. Prepayment is required, and checks should be made payable to *U.S.G.S.* For more information, contact the Pennsylvania Geological Survey library (NCIC Affiliate) at 717-783-8077, or NCIC-Mid Continent, U.S. Geological Survey, 1400 Independence Road, Rolla, MO 65401 at 314-341-0851.

COUNTY TOPOGRAPHIC MAPS

During 1986, the Pennsylvania Geological Survey and the Topographic Division of the U.S. Geological Survey continued their cooperative program to prepare and maintain topographic maps for Pennsylvania.

One series of topographic maps prepared as part of the program is the 1:50,000-scale county map. This series of maps shows (1) landforms through the use of contour lines; (2) surface features, including rivers, streams, and lakes; (3) man-made features, including woods, trails, railroads, and major buildings; and (4) political boundaries, including township, borough, and city lines. The multicolored maps have contours (inverval 20 feet) printed in brown, man-made features in black, major roads in red, urban areas in pink, forested areas in green, water features in blue, and political boundaries in orange.

1:50,000-SCALE COUNTY TOPOGRAPHIC MAPS



The 1:50,000 maps are available for 39 counties, as shown on the index map on the preceding page.

The maps can be obtained for $4.00 each ($8.00 for Allegheny, Bucks, Centre, Lycoming, Schuylkill, Washington, and York) by writing to the U.S. Geological Survey, Map Distribution, Box 25286, Federal Center, Denver, CO 80225. Prepayment is required, and checks should be made payable to *U.S.G.S.* Lehigh County (Pennsylvania Geological Survey Map 39) is available from the State Book Store, P. O. Box 1365, Harrisburg, PA 17105. The price is $1.65 (plus 10¢ tax for Pennsylvania residents); enclose a check payable to *Commonwealth of Pennsylvania*.

For more information, contact the Pennsylvania Geological Survey library (NCIC Affiliate) at 717-783-8077, or NCIC-Mid Continent, U.S. Geological Survey, 1400 Independence Road, Rolla, MO 65401 at 314-341-0851.

New Staff of the Pennsylvania Geological Survey

Sherry G. Datres

Sherry G. Datres, who originally hails from the Bluegrass State of Kentucky, joined the Survey in April 1986 as a Clerk Typist in the Editing Section.

Prior to joining the Survey, Sherry worked for a private geologic consulting firm, where she gained extensive knowledge relating to the geologic makeup of Pennsylvania and adjacent states. Before learning about geology and groundwater, Sherry spent her time working for the U.S. Army Security Agency gathering intelligence data.

Francis W. Nanna

Frank Nanna, from Johnstown, Pennsylvania, joined the Survey in June 1986. Frank graduated from Slippery Rock University with a B.S. in recreation in 1977. After graduation he was employed by engineering firms in Texas and Pennsylvania. Frank works in the Editing Section as a Cartographic Draftsman.

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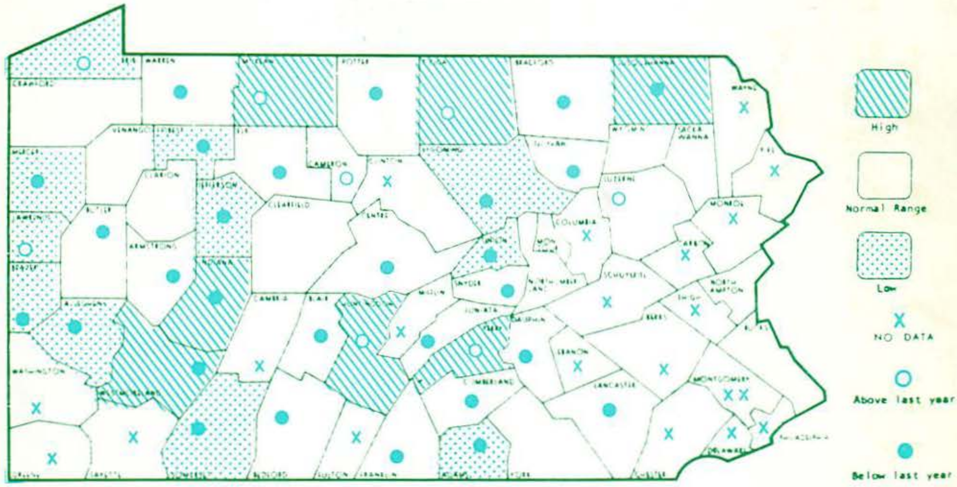
GROUNDWATER RESOURCE MAPPING

GROUNDWATER LEVELS FOR MARCH 1987



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