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Ohio Geology

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RADON REVISITED

by Michael C. Hansen

To most of the public, radon appears to have gone the way of the Hula Hoop—still around, but no longer a rage. Beginning about 1984, and for a few years after, radon was a hot news story. Homeowners were urged to test their residences with inexpensive charcoal test kits, which were readily available in grocery and hardware stores. Radon testing and mitigation companies appeared almost overnight and a multiplicity of legislative actions were pondered by lawmakers.

Although indoor radon emerged as a public health issue, geologists soon became an integral part of the story because radon is a potential health problem with a geologic origin. This colorless, odorless gas is a daughter element in the radioactive decay series of uranium, which is widespread in small quantities in rocks and sediments. Geologists have long been aware of radon and have used it in the exploration for oil and gas and even in the prediction of earthquakes. Public health officials have known about the harmful effects of high concentrations of radon from studies of uranium miners, but neither geologists nor health officials suspected that a number of homes in the country harbored potentially harmful concentrations of this inert gas. Even more surprising to geologists was the fact that some of these high-radon homes were built on rocks or sediments that had comparatively low concentrations of uranium. It quickly became apparent that there were complex geological factors involved in the occurrence of indoor radon.

Circleville esker, Pickaway County. Sand and gravel deposits, owing to their high permeability, are potential sources of indoor radon. These sediments were deposited by running water in association with Pleistocene glaciers.

The radon issue generated an unusual meld of science and politics in which the U.S. Environmental Protection Agency (USEPA) issued radon alerts to the public suggesting the indoor radon levels of 4 picocuries per liter (pCi/l) or greater posed a risk of lung cancer, although epidemiological data to support this claim, at such low concentrations, were lacking. The EPA estimates of 7,000 to 30,000 annual lung cancer deaths due to indoor radon exposure were statistical calculations based on extrapolations from studies of uranium miners, and others, who were working in poorly ventilated environments in which radon exposures were as high as several thousand picocuries. The USEPA, caught between the proverbial "rock and a hard place," was faced with either choosing a conservative approach and recommending a low "action level," or choosing a higher standard such as 10 to 20 pCi/l, which is prevalent in many European countries. Similar to the issues of asbestos and second-hand smoke, they chose the former, more conservative, approach. However, some scientists are not convinced that casual exposure to low levels of any of these carcinogens is a significant health risk and argue that many billions of dollars are spent in remediation and mitigation efforts that produce little, if any, reductions in health risks.

At the time of the initial radon campaign by the U.S. Environmental Protection Agency, which was triggered by the discovery of extremely high radon levels in a home in eastern Pennsylvania (see *Ohio Geology*, Fall 1986), little was known about how widespread the problem might be and what geologic parameters might be involved. Initial analyses of the distribution of radon across the United States relied on aerial radiometric data collected in the late 1970's and early 1980's by the U.S. Department of Energy as part of the National Uranium Resource Evaluation (NURE) project. The U.S. Geological Survey used NURE data to construct aerial radiometric maps of the country and individual states.

The Ohio map depicts some surprising patterns of comparatively high surface concentrations of uranium. Most geologists expected the higher levels to coincide with the outcrop belt of the Upper Devonian Ohio Shale, a dark, organic shale that has long been known to have elevated concentrations (10 to 40 ppm) of uranium. Although the aerial radiometric map shows some coincidence of elevated levels of surface uranium with Ohio Shale outcrops, there are areas, particularly in the central and western portions of the state, that are not associated with such outcrops and, surprisingly, resemble the distribution of glacial moraines.

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FROM THE STATE GEOLOGIST . . . by Thomas M. Berg

INDOOR RADON IN OHIO—A GEOLOGICAL HAZARD NOT TO BE IGNORED

The lead article concerning indoor radon gas in this issue of *Ohio Geology*, written by Dr. Michael Hansen, describes a geological problem that can be quite sensitive and cause considerable concern and anxiety. Geologists have the important responsibility of informing the public about the geologic hazard of indoor radon in a very factual way. Geologists would be irresponsible to overstate, understate, or ignore the presence of radon in homes, schools, places of business, or other structures.

Overstating the problem and causing undue concern can lead to apprehension, alarm, and even panic. The human body is the result of hundreds of millions of years of evolution and has the ability to deal with "normal" amounts of deleterious substances and various forms of natural radiation in our environment. Overstating the problem can also open the door to unnecessary mitigation and investment of large amounts of money in needless structural alterations. The national radon "scare" of the mid-1980's led to the establishment of many highly successful and lucrative radon-detection and radon-mitigation firms.

Understating the problem can lead to tragic consequences. The U.S. Environmental Protection Agency (USEPA) believes that about 7,000 to 30,000 lung cancer deaths each year in the United States may be attributed to radon. The USEPA also reminds us that about 85 percent of all lung cancer deaths are due to smoking. Radon concentration is measured in "picocuries per liter" (pCi/l). The average concentration of radon outdoors is about 0.2 pCi/l, and the average normal concentration of radon indoors is about 1 pCi/l. It is common practice today in the United States to recommend mitigation if indoor levels are 4 or more pCi/l. The USEPA estimates that exposure to about 15 pCi/l is comparable to smoking one pack of cigarettes each day. Continued exposure to about 100 pCi/l would be a greater risk than having 20,000 chest x-rays in a year. Because they are in stages of growth and development, I believe that the greatest concern should be for the welfare and good health of infants, children, and pregnant women. If a home is occupied by such persons, I would recommend mitigation if long-term tests indicate concentrations in primary living areas exceeding 4 pCi/l.

Ignoring the problem is scientifically irresponsible. The most important action to take is to test your home, school, church, workplace, or other structure where you are likely to spend a large amount of time. The best test is one which measures radon concentration over a long period of time—a month or more. Radon concentrations can be affected by meteorological conditions, including atmospheric pressure. A spuriously low or high observation can result when a testing device is deployed for only a day or so. A device such as an alpha track-etch detector deployed for a month or two will give a more accurate recording of average radon concentration. I learned that ignoring the radon problem can be a terrible mistake. In another state in the mid-1980's, I had a call from a very anxious person who was upset by the many news reports about the radon issue. I told the person not to panic, but to be sure to conduct tests. The basement of the home had concentrations greater than 300 pCi/l! With surprises like that, we cannot ignore the problem.

Commonly, radon concentrations exceeding 4 pCi/l in a structure can be remedied quite simply by proper ventilation. In some cases, much more expensive action must be taken such as installing subslab ventilation conduits. As with serious surgery, it is probably wise to get a second opinion if great expense is recommended.

Concentrations of indoor radon are a function of both the underlying geology and the architecture of the structure. Detailed bedrock geologic maps and detailed surficial materials maps can greatly assist in identifying areas that may have a greater radon risk than others. Site-specific determinations must rely on tests conducted in each structure. Citizens should support statewide geologic mapping to identify and prioritize areas for site-specific testing.

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SURVEY REORGANIZES

In an effort to improve services to the public, the Division is undergoing significant physical reorganization. Perhaps the most noticeble change for visitors to the Survey is that the former Department of Natural Resources Publications Center has, in part, been moved to Building C. Department publications, other than those of the Division of Geological Survey, are available from the new Public Information Center administered by the Office of Public Information and Education. Donna Schrappe, an employee of the Survey since 1973, has transferred to the Department Publications Center. Donna has been responsible for the mailing list and mailing of *Ohio Geology* since its inception in 1981.

The Division of Geological Survey has remodeled space on the second floor of Building B to form the "Geologic Records Section." This area will house all publications of the Division, topographic maps, and all geologic records, including oil and gas maps, township maps, well logs, stratigraphic sections, abandoned-mine maps, and other information and records on the geology of Ohio. The records and maps of the Regional Geology Section and the Subsurface Stratigraphy and Petroleum Geology Section have become part of the Geologic Records Section. Ample space has been provided for Survey customers to examine records and maps and to make copies of these data. Many staff geologists also have or will soon move to different offices within Building B as part of our physical reorganization.

LABORATORY AND DRILLING PROGRAMS

In order to become more cost-effective, the Division's sedimentology and geochemistry laboratories have been greatly reduced in size and capability. Some equipment has been retained for textural analyses and sample preparation, but the majority of items used in chemical analyses were donated to other departments of state and to geology departments at state universities in Ohio. Like some other state geological surveys, we believe it will be more economical to have chemical analyses done on a contract basis.

The Survey's core-drilling program has been discontinued while the accelerated statewide bedrock mapping program is underway. Core-drilling rigs and support equipment are now in storage at the Survey's core repository in Columbus. Drillers Mike Mitchell and Roy Dawson have transferred to the Division of Reclamation; Assistant Driller Bill Dunfee has transferred to the Division of Oil and Gas; Assistant Driller Mark Clary has left the Department.

If core drilling is needed during the statewide mapping program, it will be more economical to have it done on contract. When our detailed bedrock mapping program is resumed and our Quaternary mapping program is reestablished, the Survey's drilling program will be reevaluated.

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Health authorities, in conjunction with television stations and sponsoring businesses, mounted large programs to encourage homeowners to purchase radon test kits. Dayton and Columbus, in particular, initiated extensive campaigns. Partly as a result of this publicity, more than 50,000 homes across Ohio were tested.

Comparatively large public interest in radon in the late 1980's, and a lack of information on geologic controls on radon distribution, spurred a number of research efforts by faculty and students at several universities in Ohio. Investigations included the occurrence of radon in ground water, glacial deposits, and the Ohio Shale, and development of a database for indoor radon measurements and their correlation with geologic deposits.

The latter study, which was done at the University of Toledo through a grant from the Ohio Air Quality Development Authority, is the subject of a new Division of Geological Survey publication by James A. Harrell, John P. McKenna, and Ashok Kumar. This 36-page report, Report of Investigations No. 144, *Geological controls on indoor radon in Ohio,* compared radon levels with geologic features across the state. More than 50,000 radon measurements in 1,270 zip code areas were available; however, only 698 of these zip code areas had five or more measurements—considered a minimum by the authors for statistical validity.

These data indicate that 64.9 percent of the zip code areas in the state have average indoor radon levels below the U.S. EPA "action level" of 4 pCi/l. The national average is 93 percent. In Ohio, 4.7 percent of the zip code areas had radon levels above 8 pCi/l. Nationally, about 1.6 percent of homes exceed 8 pCi/l. On a county basis, 38 percent (33) of Ohio's 88 counties were above 4.0 pCi/l, but only Licking County in east-central Ohio was above 8.0 pCi/l (geometric mean of 11.5 pCi/l for the county). Seven counties—Carroll, Fairfield, Franklin, Harrison, Knox, Pickaway, and Ross—had geometric mean indoor radon concentrations between 6 and 8 pCi/l.

Geometric mean indoor radon concentrations for Ohio counties (from Harrell, McKenna, and Kumar, 1993).

RADON AND GEOLOGY IN OHIO

Although Ohio does not appear to have radon concentrations as high as those in some states, we are well above the national average. Geologists are intrigued by the origin and distribution of these elevated readings. As expected, there seems to be some correlation between elevated indoor radon and the outcrop area of the Ohio Shale, but there also is a coincidence between elevated indoor radon and glacial deposits. The highest radon levels are associated with Wisconsinan deposits in the Scioto and Miami Lobes, and particularly the Scioto Lobe.

Harrell, McKenna, and Kumar discount the presence of crystalline (igneous and metamorphic) erratics from the Canadian Shield as the primary source of uranium in these glacial deposits because the concentration of these materials is so volumetrically low. They conclude that much of the radon is derived from fragments of the uraniferous Ohio Shale that have been incorporated into the till and other glacial deposits by the glaciers.

Another probable uranium source in the glacial deposits is soil developed from the prolonged, deep weathering of carbonate rocks (limestone and dolomite) by solution. This process removes the soluble carbonate fraction, but leaves an insoluble residue of clay minerals, iron oxide, titanium dioxide, and other compounds, including uranium-bearing minerals. Although carbonate rocks generally have low (less than 3 ppm) uranium, the chemical weathering process concentrates this element in the residual soil. Commonly, under the right climatic conditions, reddish-brown soil known as terra rossa develops on the weathered limestone. It is possible that thick terra rossa soils developed on the limestone and dolomite bedrock of western Ohio prior to glaciation. Most of this material was removed by each of the three or more glaciations that covered up to two-thirds of the state. Possible remnants of terra rossa soil can be seen in some quarries in central Ohio where small sinkholes and fissures in the limestone contain red terra rossa. Each succeeding glacier incorporated till from preceding glaciers; most of the uranium of terra-rossa origin now resides in the uppermost, and most recent, Wisconsinan glacial deposits.

Numerous geological studies of radon occurrence have concluded that permeability of rock, sediment, or soil is a key factor in elevated levels of indoor radon. This gas has a short half life (3.8 days) and cannot travel long distances except in unusual circumstances. Consequently, dense, impermeable rocks or sediments with comparatively high uranium content may have a low potential to yield high indoor radon in overlying homes.

On the other hand, rocks or sediments (such as sand and gravel) that have low uranium concentrations but high permeability may yield relatively high radon values. Harrell, McKenna, and Kumar found a direct correlation between zip code areas with elevated radon levels and the distribution of sand and gravel deposits in the state. They speculate that the radon in these deposits is derived from uranium in the Ohio Shale or in other geologic source materials.

Studies of chert (flint) in neighboring Indiana have demonstrated that this rock has more than twice as much uranium as other

Contact between the uranium-rich Huron Member of the Ohio Shale (Upper Devonian) with overlying till of Wisconsinan age, Showse Park, Lorain County. Pleistocene glaciers eroded large amounts of Ohio Shale and incorporated these fragments in tills. Note vertical cracks in the till—these fissures provide avenues for upward migration of radon. Survey geologist and editor Merrianne Hackathorn points to the contact. Photo by David B. Buchanan.

rock types within the same formation. No studies of uranium concentrations in chert have been done in Ohio, but Harrell, McKenna, and Kumar point out that the zip code with the highest average radon level in Licking County (16 pCi/l) is located on Flint Ridge, an extensive flint/chert deposit of Pennsylvanian age.

In some areas of the country it is thought that ground water may be a significant source of indoor radon. The gas is released when the water is aerated, such as in a shower. The USEPA estimates that 10,000 pCi/l of radon in ground water would release 1 pCi/l of radon into the air. Other studies suggest that 1,000 pCi/l would be required to elevate indoor-air radon by 1 pCi/l. Several studies of radon in Ohio ground water show no levels above 10,000 pCi/l, and most readings are below 1,000 pCi/l. These data suggest that radon in ground water in Ohio may not be a significant problem.

Harrell, McKenna, and Kumar have done an admirable job in collecting and interpreting a large amount of information on radon across the entire state. Any Ohioan who has an interest or concern about radon will find useful information in this report. Many people, particularly those involved in some aspect of real estate, will find the appendix to be of particular value. Two tables give radon values by county and by zip code, respectively. These tables give the number of measurements for each entity, median, geometric and arithmetic means, first and third quartiles, and minimum and maximum values. Standard deviations and coefficients of variation also are included in the tables. Although such assemblages of data cannot predict radon values for individual homes, they do provide a suggestion of the potential for radon problems in a particular geographic area.

Report of Investigations No. 144 includes full-page maps of the state that present the distribution of radon by county and by zip code and in correlation to bedrock geology, glacial geology, Ohio Shale outcrop, and sand and gravel deposits. Additional maps show bedrock geology, glacial geology, and zip code distributions of radon correlated with surface concentrations of uranium detected by aerial surveys. This publication is available from the Survey for $3.00 plus $0.18 sales tax and $2.00 mailing ($5.18 total). Credit-card phone orders can be placed by calling 614-265-6576.

ADDITIONAL INFORMATION

The Division of Geological Survey can answer questions pertaining to the geology of radon. Please call 614-265-6580.

The Bureau of Radiological Health of the Ohio Department of Health is Ohio's lead agency on radon and can answer questions and provide literature on radon mitigation, licensing, and legislation. They can be contacted at 246 N. High St., P.O. Box 118, Columbus, Ohio 43266-0118. Telephone: 800-523-4439 (toll free) or 614-644-2727.

ACKNOWLEDGEMENT

We thank Dr. James A. Harrell of the Department of Geology, University of Toledo, for his assistance with this article.

FURTHER READING

Cole, L. A., 1993, Element of risk: The politics of radon: American Association for the Advancement of Science Press, 246 p.

Hansen, M. C., 1986, Radon: Ohio Division of Geological Survey, Ohio Geology, Fall issue, p. 1-6.

Otton, J. K., 1992, The geology of radon: U.S. Geological Survey, 28 p.

LAKE ERIE AND LAKE ST. CLAIR HANDBOOK

Wayne State University Press, Detroit, has published *Lake Erie and Lake St. Clair handbook*, a 469-page, softbound volume edited by Dr. Stanley J. Bolsenga, a research hydrologist with the Great Lakes Environmental Research Laboratory in Ann Arbor, Michigan, and Dr. Charles E. Herdendorf, Professor Emeritus of Limnology and Oceanography at The Ohio State University and former head of the Division of Geological Survey's Lake Erie Geology Section. The volume is illustrated by 265 line drawings, maps, and tables and is intended to appeal to a general audience interested in these lakes.

Following the introduction, the handbook has major divisions covering the lithosphere, atmosphere, hydrospere, and biosphere. Each of these chapters is a comprehensive overview of these particular subjects as they apply to Lake Erie and Lake St. Clair. Numerous illustrations and maps accompany the text.

Geological features are described in the chapter on the lithosphere. This chapter describes the physiography and topography of the lake basins and the bathymetry of the lakes. Discussions of bedrock geology include the bedrock units and their distribution, structure, mineral resources, fossils, and development of caves and sinkholes. There is a simplified but comprehensive discussion of the development of modern Lake Erie, ranging from preglacial drainage, through glaciation, through evolution of lake stages and their beach ridges.

The handbook will be of value to anyone with an interest in Lake Erie and Lake St. Clair. Numerous tables provide a handy reference for information such as islands and major reefs, including their areas and shoreline lengths, and morphometry of Lake Erie and its three basins. Chapters on the atmosphere, hydrosphere, and biosphere are similarly detailed and illustrated.

The ***Lake Erie and Lake St. Clair handbook*** is available for $19.95 plus $2.50 shipping ($22.45 total) from Wayne State University Press, The Leonard N. Simons Building, 5959 Woodward Ave., Detroit, Michigan 48202.

USGS BOOKLET ON THE GEOLOGY OF RADON

The U.S. Geological Survey has published a booklet, *The geology of radon*, that provides a nontechnical discussion of radon and the geologic factors that control the generation and migration of this radioactive gas. The booklet is authored by James K. Otton of the U.S. Geological Survey, a geologist who has been active in both radon research and public service since this topic became of widespread public interest in the mid-1980's.

This 29-page booklet contains numerous color maps and diagrams that clearly illustrate topics such as the origin and distribution of radon, radon generation and movement, entry into buildings, radon in water and soil, and the value of geologic maps in radon studies. The booklet also contains a list of important references and a list of sources for radon information.

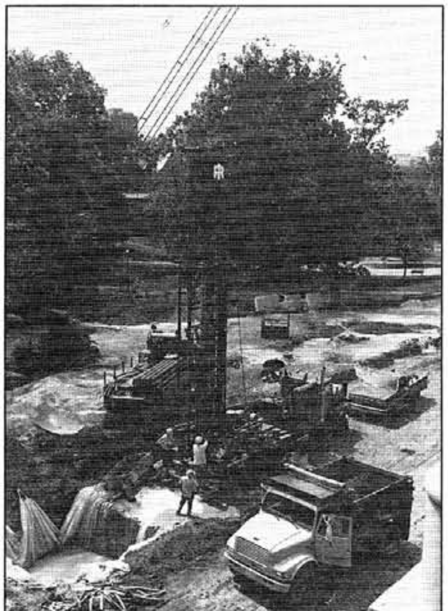
Single copies of ***The geology of radon*** are available at no charge from U.S. Geological Survey, Map Distribution, Federal Center, Box 25286, Denver, Colorado 80225. FAX orders: 303-236-1972.

NATIONAL SEISMIC NETWORK BOREHOLE AT OSU

The U.S. Geological Survey has committed to establishing a nationwide network of state-of-the-art seismographs in order to quickly determine the magnitude and location of any earthquake in the country of 2.5 magnitude or greater. These broadband, digital instruments utilize satellite telemetry to relay data to a central recording facility at the USGS's National Earthquake Information Center (NEIC) in Golden, Colorado.

The Division of Geological Survey was contacted by the USGS early in the National Seismic Network program for proposed instrument locations in the state. The Division, in consultation with Dr. Ralph Von Frese of the Department of Geological Sciences at The Ohio State University, suggested that the National Seismic Network instrument be placed in a 300-foot-deep borehole to be located in the basement of a soon-to-be-constructed addition to Mendenhall Laboratory on the OSU campus. The Division agreed to provide the borehole for the instrument.

In late August 1993, Mendenhall Laboratory construction schedules called for drilling of the borehole. Sprowls Drilling Company of Sunbury, Ohio, was the low bidder on the project and began drilling on August 19th. The borehole location, selected by the building architect on the basis of location within the building, was only about 20 feet away from the site of a 220-foot-deep Division of Geological Survey test core hole drilled in January 1991.



Sprowls Drilling Company, Sunbury, Ohio, drilling borehole in the basement of a new addition to Mendenhall Laboratory, Department of Geological Sciences, The Ohio State University.

Drilling progressed without incident and 10-inch casing was set to a depth of 80 feet. However, at a depth of 125 feet, in the Columbus Limestone (Middle Devonian), the drill suddenly dropped 6 feet and a gray mud began to emerge from the hole. It quickly became apparent that a cavern had been encountered, and drilling was halted in order to determine the best method of dealing with this situation.

Division drilling advisor Robert T. Randall, of PCA, Inc., Wooster, Ohio, suggested that we attempt to plug the void by introduction of lost-circulation materials and cement. This course of action was necessary because 7-inch-diameter casing, which would house the borehole seismometer, had to be set to a depth of 300 feet. If the cavern were not plugged, the 7-inch casing would be directly exposed to moisture and seismic-signal integrity would be compromised.

More than 1,000 bags of cement were introduced into the cavern in two separate attempts by Universal Well Services, Inc. Neither attempt was successful in plugging the cavern and the decision was made to abandon the hole. Architectural considerations precluded the possibility of moving the hole to another location beneath the building site.

Universal Well Services, Inc., pumping cement into the borehole in an attempt to plug a cavern encountered at a depth of 125 feet.

The Department of Geological Sciences, The Ohio State University, and the U.S. Geological Survey agreed to contribute financially to the project when the decision was made to attempt plugging. Ed Medina and Jim Taggart of the U.S. Geological Survey provided expertise throughout the project.

Our sincere thanks go to Gary Sprowls and the Sprowls Drilling Company for their superb effort and cooperation and to Dan Arnold and Universal Well Services for donating part of the cement job and providing the remainder at their cost. Dr. Charles Summerson of the Department of Geological Sciences, The Ohio State University provided invaluable service in coordinating the activities of the Survey, the drilling contractor, and the building contractor. Our particular thanks go to Bob Randall of PCA, Inc., who donated many hours of his time and expertise to the Survey as our drilling advisor on this project.

At this juncture, no additional funds are available for another borehole. Surface sites in central Ohio are currently being evaluated and we anticipate that the National Seismic Network Station will be installed in the near future.

—Michael C. Hansen

PALEONTOLOGICAL AWARD FOR MINERAL INDUSTRIES AND LANDOWNERS

The Paleontological Society has established a Presidential Citation award to recognize the efforts of quarry, pit, and mine operators and private landowners who have demonstrated exemplary cooperation and assistance with the preservation, salvage, or scientific study of fossil specimens. This award was created to recognize the efforts of many mineral extraction companies in assisting professional paleontologists in saving unique fossil specimens or deposits of specimens from destruction during quarrying operations. In many instances, heavy equipment has been made available to extract specimens.

The first Presidential Citation award was given to the Waukesha Lime & Stone Company of Waukesha, Wisconsin, for their 15-year effort to preserve and recover a unique occurrence of Silurian soft-bodied fossils. Nominations for Presidential Citations should include a brief description of the contributions of the nominee and should be sent to the Secretary of the Paleontological Society, Dr. Donald L. Wolberg, New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico 87801.

NEW ROCK VIDEO

The U.S. Bureau of Mines has produced a video entitled *Out of the Rock.* This excellent video takes a broad look at the importance of minerals and mining in the past and present and the technological challenges of the future. It discusses the formation of mineral deposits and how minerals are finite, thus requiring recycling and the substitution of more abundant minerals for rarer ones. Environmental issues are addressed, as well as the need for improved mining and refining techniques and workplace safety. The video is approximately 30 minutes long and is recommended for anyone who is interested in understanding how geology, mineral resources, mining, and recycling affect us daily.

The video is available on loan in 16-mm, 1/2-inch VHS, or 3/4-inch U-Matic formats from the U.S. Bureau of Mines. Bureau films may be borrowed by any responsible group or individual on a free-loan basis; borrowers pay only return postage. For a free catalog of available films, or to borrow a copy of *Out of the Rock,* write to the U.S. Bureau of Mines, Audiovisual Library, Cochrans Mill Road, P.O. Box 18070, Pittsburgh, Pennsylvania 15236. Please include your area code, phone number, preferred and alternate showing dates, and format required. The video can also be purchased for $7.50 from the SME Foundation for Public Information and Education, 8307 Shaffer Parkway, Littleton, Colorado 80127 (telephone: 303-973-9550).

BEDROCK GEOLOGY MAP OF PIQUA QUADRANGLE AVAILABLE

The Division of Geological Survey recently published Map No. 6,[1] *Regional bedrock geology of the Ohio portion of the Piqua, Ohio-Indiana 30 x 60 minute quadrangle*, as the first in a series of full-color bedrock geology maps covering the state at a scale of 1:100,000 (1 inch represents about 1.5 miles). The map was authored by Division geologist Gregory A. Schumacher, who used data from outcrops, oil and gas and water wells, and cores drilled specifically to obtain stratigraphic information. The geology was compiled on 1:24,000-scale (1 inch represents about 2,000 feet) topographic base maps. These detailed maps also are available from the Survey as part of the open-file map series.

The Piqua map covers a 3,150-square-mile area in western Ohio that includes Shelby County, a large portion of Darke and Miami Counties, and portions of Auglaize, Champaign, Clark, Logan, and Mercer Counties. Bedrock geology of the area had not been mapped since the 1870's, during the tenure of John S. Newberry as State Geologist. The bedrock is generally covered by glacial sediments, which limit the opportunities for direct observation.

Mapped units include undifferentiated Upper Ordovician, Lower Silurian sub-Lockport undifferentiated, Lower Silurian

[1]This map series was created in 1993 to encompass major stand-alone published maps distributed by the Survey, particularly the new 1:100,000 regional bedrock geology maps. The series includes the *Geologic map of Ohio*, *Glacial map of Ohio*, and others.

Location of Piqua 30 x 60 minute quadrangle

Lockport Dolomite, and Upper Silurian Salina undifferentiated, Greenfield Dolomite, and Tymochtee Dolomite. The distribution of these units as seen on the map clearly defines preglacial buried valleys that were part of the preglacial Teays system. The main Teays valley cuts across the northeastern portion of the quadrangle and is filled with more than 580 feet of glacial sediment.

The course of the Teays is thought to coincide with a northwest-southeast-oriented segment of a Precambrian rift system, known as the East Continent or Fort Wayne rift, that is the principal seismogenic structure in Ohio. Numerous felt earthquakes have occurred along this rift, including events in 1937 that caused damage in Anna and other Shelby County communities.

The Piqua quadrangle was produced as part of the National Geologic Mapping Program, known as STATEMAP. The work was conducted under a cooperative agreement between the Division and the U.S. Geological Survey. When mapping has been completed for all 34 of the 30 x 60 minute quadrangles in Ohio, a new state geologic map will be prepared. This state map will replace the existing state geologic map prepared under the direction of State Geologist John A. Bownocker in 1920.

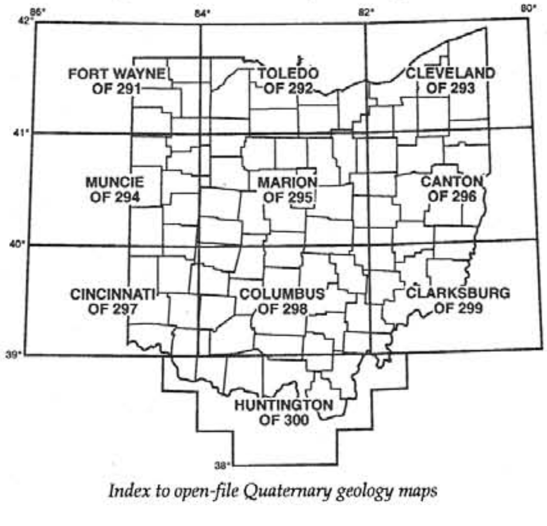
Included on the map sheet is an extensive text that describes the stratigraphy and the economic and environmental geology of the area. A columnar section, two cross sections, and a list of references are included. This map, and others in the series, will be an important resource for the location, development, and protection of mineral resources; the siting of landfills, schools, hospitals, highways, and other public and private facilities; and for planning and zoning activities.

Map No. 6 is available from the Division of Geological Survey, Ohio Department of Natural Resources, 4383 Fountain Square Drive, Columbus, Ohio 43224-1362, for $12.00 plus $0.69 tax and $3.00 mailing ($15.69 total). Credit-card phone orders can be placed by calling 614-265-6576.

OPEN-FILE QUATERNARY MAPS AVAILABLE

Regional maps depicting the Quaternary geology of Ohio are now available in the Survey's Open-File Map Series. The maps have been compiled by Survey geologists C. Scott Brockman, Dennis N. Hull, Richard R. Pavey, and Robert G. Van Horn using data collected by Jane L. Forsyth, Richard P. Goldthwait, and George W. White. Ten maps, at a scale of 1:250,000, provide complete coverage of the state. The maps are on mylar and are reproduced as black-line paper copies. More than 40 map units are delineated statewide, including lacustrine and outwash deposits in unglaciated southeastern Ohio.

These maps will be particularly useful to a variety of individuals and businesses, including planners, engineers, construction companies, and others who deal with surficial materials in the state. These maps are available from the Survey for $4.00 each plus $0.23 tax and $2.00 mailing. Please consult the following list and index map for quadrangle names and map numbers.



Index to open-file Quaternary geology maps

OPEN FILE NUMBER	MAP TITLE
OF-291	Quaternary geology of Ohio, *Ft. Wayne quadrangle:* by J. L. Forsyth and R. R. Pavey.
OF-292	Quaternary geology of Ohio, *Toledo quadrangle:* by R. R. Pavey and R. P. Goldthwait.
OF-293	Quaternary geology of Ohio, *Cleveland quadrangle:* by D. N. Hull.
OF-294	Quaternary geology of Ohio, *Muncie quadrangle:* by J. L. Forsyth and R. R. Pavey.
OF-295	Quaternary geology of Ohio, *Marion quadrangle:* by R. P. Goldthwait and R. R. Pavey.
OF-296	Quaternary geology of Ohio, *Canton quadrangle:* by D. N. Hull and G. W. White.
OF-297	Quaternary geology of Ohio, *Cincinnati quadrangle:* by J. L. Forsyth and C. S. Brockman.
OF-298	Quaternary geology of Ohio, *Columbus quadrangle:* by R. P. Goldthwait and R. G. Van Horn.
OF-299	Quaternary geology of Ohio, *Clarksburg quadrangle:* by R. R. Pavey.
OF-300	Quaternary geology of Ohio, *Huntington quadrangle:* by R. P. Goldthwait and R. R. Pavey.

ROBERT L. ALKIRE 1910-1993

It is with regret that we report the death of former Survey geologist and long-time oil and gas consultant Robert L. Alkire on June 3, 1993, in Columbus. Bob is survived by his wife, three children, and seven grandchildren.

Bob was born on September 20, 1910, in Columbus. As a teenager he contracted tuberculosis and spent some time in a sanitarium. After his health improved, he went to Phoenix, Arizona, for complete recovery. During this Arizona sojourn, Bob developed an interest in geology and began prospecting for minerals in the nearby mountains.

Bob returned to Ohio and began pursuit of a career in engineering. He eventually transferred to the University of Pittsburgh, from which he received a degree in petroleum geology in 1938. Bob's first professional job was with Gulf Oil as a seismic crew leader in Illinois. After an honorable discharge from the Navy for health reasons, Bob worked for DuPont in Charleston, West Virginia, during World War II. After the war, he served as chief geologist and engineer for Southeastern Corporation, also in Charleston.

In 1948, Bob joined the Survey as oil and gas geologist under State Geologist John H. Melvin. The Survey offices were in the basement of Orton Hall on the campus of The Ohio State University, and the staff consisted of Melvin, principal geologist Raymond E. Lamborn, and secretary Ethel Dean. This period was at the beginning of the tenure of Melvin as State Geologist and the beginning of the expansion of the Survey.

The first project assigned to Bob was to

Robert L. Alkire at the Survey offices in Orton Hall, The Ohio State University, 1951.

prepare an oil and gas fields map of Ohio. He soon learned that there were no complete oil and gas pool maps and, indeed, no oil and gas well location maps. Bob, with the aid of cartographer Hal Flint, began the task of transferring industry location and pool maps to a common base map. Literature, newspaper articles, and the memories of "old timers" were searched in order to determine the correct pool names. In some cases, no name existed and a local stream, nearby town, or a township became the name of the oil or gas pool. The first edition of the *Oil and gas fields of Ohio* map was published in 1948. The first printing of 2,500 copies sold for 50 cents each and was soon sold out. It was not until 1953 that sufficient funds were available for reprinting.

In 1949, the Survey published Bob's map of the *Oil and gas pipelines of Ohio.* Bob obtained the data for this map from many different companies that had pipelines and compiled these data on the same base map used for the oil and gas fields map. He wrote that his original idea was to superimpose the pipelines on the oil and gas fields map, but he soon realized that there was just too much information. The pipelines map was the first of its kind to be published by a state geological survey.

From 1951 through 1963, Bob compiled and published yearly oil and gas statistics for Ohio, even though he left the Survey in 1955 to become an oil and gas consultant. Bob continued in the consulting business for the remainder of his career and provided his expertise to many large corporations, including Ford Motor Company, American Electric Power Company, Republic Steel Corporation, U.S. Steel Company, and numerous federal and state agencies.

Bob's occasional visits to the Survey were always a delight. He was outspoken and direct and never shy about giving a compliment on a product or service rendered by the Survey. He was equally forthright about our flaws as well, but these criticisms were constructive. Bob's stories about his days at the Survey, and the personalities of the geologists of that time, were always interesting and usually amusing. Bob will be missed by his family, friends, and colleagues.

—Michael C. Hansen

We thank Jerry Picker of Columbus, former associate of Bob Alkire, for providing biographical data and assistance with this article.

STAFF NOTES

Scudder D. Mackey joined the Survey in June 1992 as Head of the Division's Lake Erie Geology Section in Sandusky. The Survey was able to fill this position, which has been vacant since the departure of Dr. Charles H. Carter to the University of Akron in 1982, because of the availability of federal monies for a cooperative program with the U.S. Geological Survey to study coastal erosion dynamics in Lake Erie.

Scudder is originally from Binghamton, New York. He received a B.S. degree from Hobart and William Smith College in Geneva, New York, an M.S. degree in geology from the University of Wisconsin, and a Ph.D. in geology from the State University of New York at Binghamton. Before returning to school to work on a doctorate, Scudder worked in the petroleum industry for Atlantic Richfield, Koch Exploration Co., and as a consultant.

Scudder is married and has two daughters and a son. He enjoys sailing, bicycling, and computers as hobbies.

Danielle A. Foye began working for the Survey in May 1992 as a geology technician at the Lake Erie Section in Sandusky. This position is part of the cooperative program with the U.S. Geological Survey to study coastal erosion dynamics in the lake.

Danielle is from Lakewood, Ohio, and received a bachelor's degree in geology from Wright State University in 1991. She minored in photography at Wright State and is an accomplished photographer, a skill that will be welcomed at the Survey. Danielle enjoys the multitude of field and laboratory duties she performs as part of the coastal dynamics project.

In addition to photography, Danielle enjoys a variety of participant sports, including volleyball. She was formerly a competitive swimmer.

ROSE RUN REPORT NOW AVAILABLE

The results of a two-year investigation of the Upper Cambrian Rose Run sandstone in eastern Ohio and western Pennsylvania have been published. The study was conducted by the Ohio and Pennsylvania Geological Surveys in a cost-sharing agreement with the U.S. Department of Energy under the auspices of the Appalachian Oil and Natural Gas Research Consortium, which consists of several state geological surveys and West Virginia University. The report, titled *Measuring and predicting reservoir heterogeneity in complex deposystems: the Late Cambrian Rose Run sandstone of eastern Ohio and western Pennsylvania,* was authored by Ohio Survey geologists Ronald A. Riley, Mark T. Baranoski, and Richard W. Carlton and Pennsylvania Survey geologists John A. Harper and Christopher D. Laughrey.

The 257-page report contains 125 figures, including numerous maps, cross sections, seismic lines, and photographs of rock thin sections, six tables, and several case studies of Rose Run wells.

The Rose Run report is available from the Ohio Division of Geological Survey for $10.00 plus $2.00 mailing and $0.58 Ohio sales tax.

NEW HEAD OF TECHNICAL PUBLICATIONS SECTION

In late 1992, Division Chief and State Geologist Thomas M. Berg appointed Edward V. Kuehnle as Head of the Technical Publications Section. Ed fills the vacancy created by the retirement of Philip J. Celnar in March 1992.

Ed has been a cartographer in the Technical Publications Section since he came to the Survey in 1984 after receiving a B.A. degree in geography from the University of Cincinnati and working as a cartographer in the private sector. During his years as a cartographer, Ed has worked on a variety of Survey maps and publications, including the design and layout of *Ohio Geology*. This broad experience in various aspects of cartography gives Ed the qualifications to supervise the many aspects of publication production and printing that are required to produce quality publications. He faces many new challenges as the Survey changes the approach to typesetting and becomes more computerized in the production of publications.

Ed, a Cincinnati native and Vietnam veteran of the Marine Corps, lives in Columbus with his wife and son. He enjoys sports and cars as hobbies.

MINERAL INDUSTRIES REPORT AVAILABLE

The *1992 Report on Ohio mineral industries*, compiled by Survey geologist and mineral statistician Sherry L. Weisgarber, is now available from the Division of Geological Survey. The report provides production, sales, and employment statistics for all Ohio mineral industries, including coal, limestone/dolomite, sand/gravel, sandstone/conglomerate, clay, shale, gypsum, salt, and peat, plus production and value statistics for oil and gas. The report includes alphabetical and by-county directories of coal and industrial-mineral mine operators and a map of the locations of reporting producing coal mines and all industrial-mineral mines in 1992.

Feature articles in the 1992 report are "Coal availability: estimating coal resources available for development," authored by Survey geologist Allan G. Axon, and "Ohio's legacy in stone," authored by Joseph T. Hannibal, Cleveland Museum of Natural History.

Copies of the *1992 Report on Ohio mineral industries*, which includes the map, are available from the Survey for $7.29, including tax and mailing. The map is also available separately for $3.06, including tax and mailing.

QUARTERLY MINERAL SALES, APRIL–MAY–JUNE 1993

compiled by Sherry L. Weisgarber

Commodity	Tonnage sold this quarter[1]	Number of mines reporting sales[1]	Value of tonnage sold[1] (dollars)
Coal	6,274,101	109	$153,146,676
Limestone/dolomite[2]	13,842,541	95[3]	53,880,680
Sand and gravel[2]	5,713,986	186[3]	39,148,822
Salt	686,077	5[4]	12,919,444
Sandstone/conglomerate[2]	454,886	15[3]	8,011,954
Clay[2]	273,308	27[3]	1,910,180
Shale[2]	231,065	22[3]	693,238
Gypsum[2]	48,907	1	464,617
Peat	5,499	3[3]	63,313

[1]These figures are preliminary and subject to change.
[2]*Tonnage sold* and *Value of tonnage sold* include material used for captive purposes. *Number of mines reporting sales* includes mines producing material for captive use only.
[3]Includes some mines which are producing multiple commodities.
[4]Includes solution mining.

[A NOTE TO READERS WHO HAVE ALREADY RECEIVED A COPY OF THE 1992 MINERAL INDUSTRIES REPORT: We recently discovered that some books were misprinted—pages were out of order or missing. If you have received a misprinted copy, please let us know and we will send a good copy. We apologize for any inconvenience.]

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