FALL 1986

Ohio Geology Newsletter

Division of Geological Survey

RADON

by Michael C. Hansen

The geologic equivalent of the Four Horsemen of the Apocalypse would include earthquakes, landslides, volcanoes, and, as the final, recently added member, radon gas. Fortunately, Ohio lacks one of the scourges—volcanoes—and earthquakes and landslides in the state seldom are life threatening. By comparison, radon, although silent and slow, may prove to be the most deadly of the Horsemen in Ohio.

Radon is a colorless, odorless, inert radioactive gas that, for most of us, has gone from an innocuous position on the periodic chart of the elements learned long ago in chemistry class to a public health hazard. Front-page headlines have created sufficient anxiety that radon has moved onto the list of widespread substances that are harmful to health and publicly perceived as such. However, unlike foods, drinks, medicines, and chemicals that can be consciously avoided, radon is undetectable without special measuring devices and there are few guidelines that can aid in determining if a particular home has a potential for hazardous concentrations of radon.

It has long been known to radiological health scientists that radon is responsible for increased rates of respiratory cancer among uranium miners who were sometimes exposed to elevated concentrations of radon in underground workings. In addition, these scientists have recognized small-scale indoor radon problems in buildings located on tailings from uranium operations and buildings in which uranium tailings were used as a construction aggregate. Geologists have used radon for some time in petroleum exploration and as a potential predictor of earthquakes. It was not until recently, however, that both geologists and public health officials became aware that radon was widespread in the natural environment and accumulating in buildings in potentially harmful concentrations in areas that did not exhibit particularly high levels of uranium in surface rocks and sediments.

In 1984 the widespread potential for harmful levels of radon in homes was brought into the public eye by a dramatic example in Boyertown in eastern Pennsylvania. Stanley Watras, an engineer at the Limerick Nuclear Power Plant, triggered radiation alarms at the nuclear facility each day as he left for home. It was discovered that Watras was not receiving the contamination at the plant but was bringing it to work with him. Radon monitoring in his home disclosed that radiation levels were 100 times the maximum permitted in uranium mines. Some public health officials compared these levels to a health hazard equivalent of receiving three chest x-rays per minute for life or smoking 135 packs of cigarettes per day. To date, the Watras home has the highest levels of radiation monitored in any home in the United States. Corrective measures have reduced the radiation in this home to acceptable levels. Interestingly, the home next door to the Watras house had no radon problem, illustrating the geologic complexity of predicting potential radon levels in individual homes.

Outcrop of Ohio Shale exposed along Alum Creek, Delaware County.

Outside, in the atmosphere, radon presents no health hazard because it is rapidly diluted and dispersed. Indoors, however, radon levels can build up to concentrations that create a potential health problem, especially in tightly sealed, poorly ventilated homes in areas where radon is generated from uranium in underlying rock or sediment and becomes a soil gas. In addition, there must be avenues through which the radon-bearing soil gas can move to the foundation of the home and entryways into the home such as cracks or openings for utility pipes.

How big is the problem in the United States? There is currently no accurate answer to that question, although speculative estimates by federal agencies suggest that as many as one million homes in the United States many have a radon problem. At this early stage of investigation there is no substantial data base of actual radon measurements from homes from which such conclusions can be accurately drawn. In Ohio, the extent of the problem is just as speculative as in the remainder of the country, although

continued on next page

ODNR
OHIO DEPARTMENT OF NATURAL RESOURCES

Richard F. Celeste, Governor • Joseph J. Sommer, Director

Chief's corner

by Horace R. Collins

Radon! The lead article in this issue of *Ohio Geology* deals with an obscure radioactive gas until just recently essentially unknown to almost everyone including geologists and other members of the scientific community. As editor Mike Hansen points out in his article, most people who have heard of radon remember it from high school or college chemistry as one of those elements on the periodic chart that was so unremarkable that in the everyday world it was essentially ignored.

Radon, however, has recently burst onto the scientific scene in a major way. It has only been in the last year or two that radon has been recognized as a potential public health problem. Its occurrence in Ohio has become a matter of concern only in the past six months or so. As you will read in the accompanying article, under certain conditions radon gas in high concentrations has been correlated with an increase in lung cancer.

The relatively sudden awareness of radon by the general public and the scientific community gives us a classic example of how geology must continually meet changing societal needs. Although as geologists we are not responsible for public health, our work may be of great importance to those who must track down and deal with threats to public health. Geologic conditions along with many other manmade factors obviously play a significant role in where radon may or may not be a problem.

Much work remains to be done in identifying potential areas of radon concentration. Several years ago many states, including Ohio, were surveyed by the U.S. Department of Energy as part of the National Uranium Resource Evaluation (NURE) program. This program was of a reconnaissance nature to determine if uranium might occur in commercial quantities in selected areas of the United States. This very preliminary exploratory work carried out by the NURE program gives us only a vague hint as to where radon may be a problem. It must be recalled that the maps developed for the NURE project were produced before the radon problem became obvious and were designed to evaluate the potential of commercial uranium, not to deal with radon as a distinct element. Currently available maps of uranium levels in Ohio cannot be directly related to radon levels, and it would be both premature and inaccurate to attempt such correlations.

The Division of Geological Survey through its current and past mapping activities is assisting those concerned with locating geologic conditions related to both the occurrence and transmission of radon into the environment. Other agencies dealing with public health and air quality are also examining the radon question in Ohio. Because of Ohio's relatively unfavorable geology for the formation of radon, we hope the vast majority of Ohioans will not have a problem. Again because of expected realtively low levels, those homes with slightly elevated radon levels should be able to correct their problems through improved ventilation and sealing.

SURVEY IS UNITED WAY LEADER

The Division of Geological Survey was the leading contributor to the 1987 United Way campaign from among the 19 divisions and offices of the Ohio Department of Natural Resources. A total of $2,000 was contributed by Survey employees out of a Department total of $16,733. This is the second year in a row that the Survey has achieved this distinction, even though the size of the Survey staff is smaller than that of most divisions.

OHIO GEOLOGY

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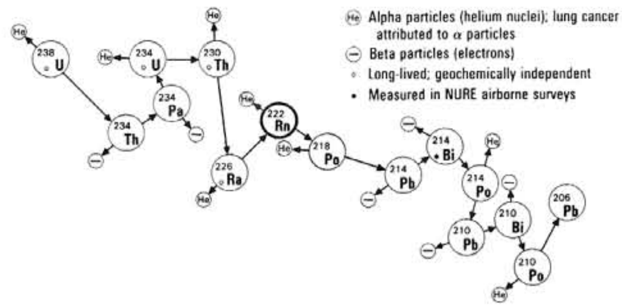
News items, notices of meetings, etc. should be addressed to the attention of the editor. Change of address and new subscriptions should be addressed to the attention of the secretary.

continued from page 1

geologic conditions in the state do not appear to be favorable for generating extremely high indoor radon levels such as have been found in some states.

WHAT IS RADON?

Radon is derived from uranium-238 through a complex radioactive decay chain and represents one in a series of daughter elements produced in the transition from uranium to lead. Radon is derived directly from radium-226. Although



Simplified uranium-238 decay series. Because it has a relatively long half-life (3.8 days), is chemically inert, is a gas, and gives off a relatively large and heavy alpha particle during its decay process, radon-222 constitutes the greatest health hazard to the general population. From Tanner (1986).

several isotopes of radon are produced from the disintegration of a radium atom, only radon-222 has a sufficiently long half-life (3.8 days) to be considered relevant to the problem of radon in homes.

Radon-222 is a potential health hazard when it becomes attached to a dust or smoke particle and is inhaled (being inert, radon does not combine chemically). If the radon atom becomes lodged in the respiratory tract it has the potential to cause cell damage when it emits a relatively large and heavy alpha particle during the process of radioactive decay.

Radon concentrations are commonly expressed by measurements such as picocuries per liter (pCi/l) or working levels (WL). One picocurie represents the decay of approximately two radon atoms per minute in about a liter of air. A working level is a measurement of the energy resulting from the generation of alpha particles in a liter of air. A common expression of this measurement is in terms of working level months (WLM), which represent a time period of exposure of about 170 hours. This unit of measurement was orginally formulated to reflect radiation exposure of uranium miners during normal working hours.

One working level is equivalent to about 200 picocuries per liter of radon (see table on p. 6), a level of radiation exposure that indicates a mitigation program should be undertaken immediately. Radon concentrations greater than 4 pCi/l indicate that remedial action should be undertaken, although the urgency for such action is perhaps not so great for levels close to 4 pCi/l as with those above about 20 pCi/l.

GEOLOGY OF RADON

Radon, as noted above, is a daughter element in the radioactive decay chain of uranium-238 and is directly derived from the decay of radium-226. Uranium is found in a variety of rocks in varying concentrations. Igneous rocks, such as granite, and metamorphic rocks, such as gneisses formed by metamorphism of uranium-bearing sediments, commonly have high concentrations of uranium. Rocks high in phosphate also tend to have relatively high concentrations of uranium. Igneous and metamorphic rocks do not crop out in Ohio and no high-phosphate sedimentary rocks are known in the state. It should be noted that the weathering of these rocks may produce residual soils that may be much higher in uranium than the original rocks.

Limestone and dolomite, sedimentary rocks that are present in abundance throughout much of the western half of Ohio, are noted for being nearly the least radioactive on the basis of bulk radioactivity. However, recrystallization of limestones and dolomites can concentrate radioactive minerals in zones of "intergranular refuse" adjacent to zones of pure calcium carbonate or calcium magnesium carbonate. Such zones of higher radioactivity are sometimes in contact with fluids moving through the rock. Elevated radon levels in some caverns are thought to be associated with such sources of radioactivity.

Uranium also is present in dark-gray, highly organic shales such as the Ohio Shale of Devonian age and the Sunbury Shale of Mississippian age. The uranium in these shales was derived from the weathering of igneous rocks and was

Outcrop area of the Ohio Shale in Ohio. In some portions of the state, north of the glacial boundary, the Ohio Shale is not exposed at the surface because of a thick mantle of glacial drift.

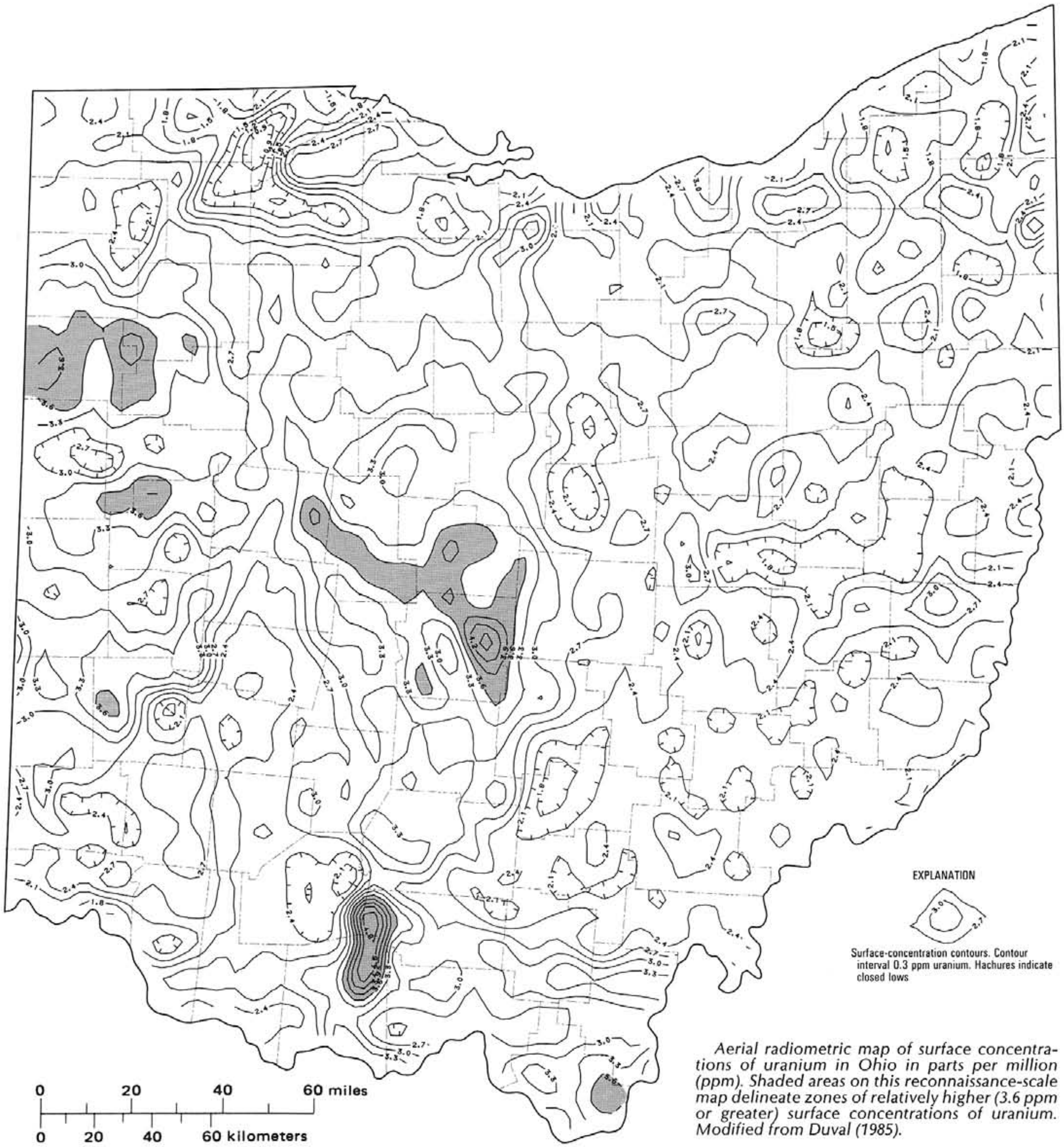
carried to the sea and deposited in reducing environments associated with organic productivity. The concentrations of uranium in the Ohio Shale are quite low, on the order of 0.003 percent (30 ppm), although concentrations of uranium may be somewhat higher along joints and outcrop surfaces where it has been secondarily concentrated by weathering. The Ohio Shale, which crops out in a north-south band through the central portion of the state and along the eastern half of the Ohio shore of Lake Erie, is capable of producing radon gas in quantities that may pose a problem for some houses that overlie this formation. However, numerous other factors, as noted below, have direct bearing on the radon potential for homes and other buildings overlying the Ohio Shale and other units.

The Ohio Shale, a unit which contains uranium, can potentially provide sufficient quantities of radon gas to create indoor-radon problems in homes or other buildings. Very thin glacial tills, as depicted in this photograph along Interstate 270 in northern Franklin County, may be ineffective in shielding structures from upward migration of radon.

Owing to their relatively short half-life (3.8 days; 90 percent will decay in 13 days), radon atoms cannot move great distances from their source in rock or sediment. Estimates of these distances range from several feet to perhaps a few tens of feet in favorable situations where rapid convection currents transport radon-bearing soil gas or fluids. Porosity and permeability of a rock or sediment are therefore important factors in the movement of radon gas to the surface. Very porous and permeable sand and gravel deposits of glacial or alluvial origin may contribute to enhanced radon availability, although their bulk radioactivity may be comparatively low. Thin sand and gravel deposits, only a few feet thick, that overlie a geologic unit with comparatively higher bulk radioactivity (such as the Ohio Shale) may yield even higher levels of radon.

Conversely, clays and muds, including clay-rich glacial tills, generally have less available radon. In many cases only several feet of such impermeable sediment can be an effective shield against migration of radon to the surface. These relationships help to explain, in part, the wide variance in indoor radon levels in homes that may overlie a radon-generating unit such as the Ohio Shale. Nearly two-thirds of Ohio is blanketed by glacial sediments, much of which is glacial till. However, the till varies considerably in thickness, sometimes within very short distances. Drift-thickness maps, such as those prepared or being prepared by the Survey for many counties in the state, are a useful tool to help in assessing the potential radon hazard for an area.

Fractures in rock such as joints or faults also can provide an avenue for radon-bearing soil gas to reach the surface. In



Aerial radiometric map of surface concentrations of uranium in Ohio in parts per million (ppm). Shaded areas on this reconnaissance-scale map delineate zones of relatively higher (3.6 ppm or greater) surface concentrations of uranium. Modified from Duval (1985).

some cases where such fractures are open for long distances, convection currents could carry this soil gas for hundreds of feet.

Radon can also enter the indoor environment through water supplies, particularly water derived from domestic wells. Radon is released from the water during showering or other activities that aerate the water. Radon in water supplies appears to be a significant problem only in areas underlain by certain types of igneous and metamorphic rocks.

RADON IN OHIO

The radon problem in Ohio is not thought to be as significant as in certain other states such as Florida, New Jersey, New York, and Pennsylvania, where rocks or sediments that are relatively rich in uranium are near the surface. However, in Ohio and in most states there exists only a small data base of actual radon measurements in homes. There is no accurate, reliable, and inexpensive method to characterize the radon potential of individual homes or groups of homes within a particular region. In addition to the geologic factors noted above, which may exhibit a high degree of variation within a small area, the nearly unlimited variability of individual homes in regard to avenues for radon entry into the basement or slab and air circulation and exchange within the structure are significant factors in indoor radon concentration.

There is a reconnaissance-scale map of Ohio that can be used as a *general* guide to radon potential of various areas in the state, although at this time there is little direct evidence that actual indoor-radon problems are significant or widespread within any of the areas of relatively higher uranium concentrations on the map (see accompanying map). This map depicts surface concentrations of uranium and is one of three in a series titled *Aerial radiometric contour maps of Ohio,* published by the U.S. Geological Survey in cooperation with the Ohio Division of Geological Survey. The other two maps in the series depict surface concentrations of thorium and potassium. These maps were prepared from data gathered by the U.S. Department of Energy during the National Uranium Resource Evaluation (NURE) program as an aid to uranium exploration in the United States. The data were gathered by aircraft equipped with high-sensitivity gamma ray spectrometers flying at altitudes of about 400 feet. East-west flight lines were spaced at 6-mile intervals and north-south tie lines were flown at 15-mile spacings.

At the time these data were gathered, many geologists recognized their potential for assessing surface concentrations of uranium for exploration purposes and the potential of radon to aid in hydrocarbon exploration, but few realized that potentially hazardous concentrations of radon could be accumulating in homes from the relatively low-level surface concentrations of uranium in most areas, including Ohio.

It cannot be overemphasized that these maps are strictly at a reconnaissance scale. The flight-line spacing is such that actual measurements were gathered over less than 5 percent of the state's surface. The uranium map therefore only broadly characterizes the surface concentrations of uranium across the state. The map cannot be used to predict the potential radon hazard in individual homes.

The uranium map does have value in characterizing the radon potential of broad areas of the state because spectrometers used in the NURE survey measured the gamma radiation produced by the decay of bismuth-214, a direct daughter of radon. Again, it must be emphasized that the data are so widely spaced and the variations in geologic conditions and individual homes are so great that the uranium map should not be used to predict the radon potential for any building. It is entirely probable that most homes within a comparatively higher anomaly on the regional uranium-concentration map would not exhibit high indoor radon. The example of the extremely high radon level in the Watras home in Boyertown, Pennsylvania, and the normal reading in the home next to it should be kept in mind. On the other hand, areas exhibiting relatively low concentrations of uranium on the regional map could, potentially, have small areas that may have relatively high radon. Such a small area could lie between the broadly spaced flight lines and, therefore, not be reflected by the map.

The map depicts surface concentrations of uranium equivalents in parts per million (ppm). Most of the state exhibits relatively low concentrations, in the range of 2 to 3 ppm, and would be expected to generate only low levels of radon. A few areas, however, exhibit slightly higher levels of uranium, although none of them can be characterized as extremely high (greater than 5 ppm).

The highest uranium concentrations indicated on the reconnaissance map are in southern Ohio at the junction of Adams, Highland, and Pike Counties. This north-south-elongated anomaly exhibits a 4.8-ppm contour line at the center. The source of this anomaly is uncertain; however, it coincides with exposures of the Ohio Shale, it is beyond the glacial boundary and therefore lacks a mantling of clay-rich glacial drift, and, perhaps coincidentally, it coincides with the location of the Serpent Mound cryptoexplosion structure and north-south-oriented faulting.

A second area of slightly higher levels of surface uranium concentration is in central Ohio in portions of Franklin and Delaware Counties, stretching northwestward across Union County and into western Logan County. It is probable that a portion of this area, particularly in eastern Franklin and Delaware Counties, and possibly in Logan County, reflects the presence of the uranium-bearing Ohio Shale.

Comparatively small and relatively low level (about 3.6 ppm) anomalies occur in portions of Van Wert, Putnam, and Allen Counties and in Auglaize and Shelby Counties. Two very small 3.6-ppm anomalies are present in western Montgomery County and in southern Lawrence County. None of these anomalies can, at this time, be correlated with geologic units or structures that are known to have increased levels of uranium. It must again be emphasized that none of these anomalies has concentrations of uranium that can be considered relatively high.

RADON MITIGATION

Radon enters a home through the portions of the structure that are in contact with the ground—basement or slab floor and foundation walls. An initial mitigation program consists of sealing cracks and joints in the floor and walls, sealing porous cinderblock, and sealing around entryways for utility pipes, floor drains, and sump pumps. Extreme cases of high indoor radon may require installation of subfloor ventilation systems that capture most of the soil gas beneath the basement or slab floor and vent it to the outside.

An additional approach to radon mitigation involves adequate ventilation of the home, particularly in areas of radon entry such as the basement or crawl space. In many newer, energy-efficient homes there is an inadequate exchange of air, which can cause the buildup of radon from relatively low levels of radon in soil gas. Increasing ventilation can reduce the level of radon. Devices such as air-to-air heat exchangers can increase the exchange of air within a structure without significant heat loss.

HOW DO YOU KNOW IF A HOME HAS A RADON PROBLEM?

At present, there is no method to predict potential radon levels in individual homes in Ohio. The great degree of variability in local geology and a similar degree of variation in home construction and ventilation make it extremely difficult, if not impossible, to make such predictions. It is possible that compilation of radon measurements from thousands of Ohio homes eventually may provide a sufficient data base to make generalized predictions of areas of the state that may have higher levels of indoor radon.

There are a variety of methods to measure indoor radon concentrations. Such measurements require devices ranging from those that must be deployed by trained personnel to

RELATIVE RADON-RISK EVALUATION CHART[1]

pCi/l[2]	WL[2]	Estimated number of lung cancer deaths due to radon exposure (per 1,000)	Comparable exposure levels	Comparable risk
200	1	440-770	1,000 times average outdoor level	More than 60 times nonsmoker risk
				4-pack-a-day smoker
100	0.5	270-630	100 times average indoor level	
				20,000 chest x-rays per year
40	0.2	120-380		
			100 times average outdoor level	2-pack-a-day smoker
20	0.1	60-210		
				1-pack-a-day smoker
10	0.05	30-120	10 times average indoor level	
				5 times nonsmoker risk
4	0.02	13-50		
			10 times average outdoor level	200 chest x-rays per year
2	0.01	7-30		
				Nonsmoker risk of dying from lung cancer
1	0.005	3-13	Average indoor level	
0.2	0.001	1-3	Average outdoor level	20 chest x-rays per year

[1]From U.S. Environmental Protection Agency (1986a).
[2]pCi/l, picocuries per liter; WL, working levels.

fairly simple devices that can be used by homeowners. These latter devices can be ordered by mail, placed in the home for a specified period of time, and then returned to the company for analysis. Results of the analysis are then returned to the homeowner.

A brochure prepared by the U.S. Environmental Protection Agency lists companies that supply radon detectors. Copies of this brochure, and other brochures, are available from the Ohio Department of Health, Radiological Health Unit, 246 N. High St., Columbus, Ohio 43266-0588. Perhaps the least expensive radon detectors that have come to our attention are available through a program established by *Practical Homeowner* magazine. These detectors are available for $11.95 each (3 for $29.95) from: Air Chek, P.O. Box 2000-PH, Penrose, North Carolina 28766.[1]

When evaluating the results of a radon measurement in an individual home, it should be kept in mind that radon levels may vary from place to place within the home and also may vary seasonally, daily, and even hourly. A home that shows undesirable levels of radon during the winter, when the house is closed up, may exhibit much lower levels during the summer, when windows are open. In addition, a basement may exhibit much higher radon levels than an upstairs living area. It should also be kept in mind that potential health problems from radon are thought to be a result of long-term exposure (perhaps 20-30 years) to elevated levels of this gas.

ACKNOWLEDGMENTS

We thank Joseph S. Duval, James Otton, and Allan B. Tanner of the U.S. Geological Survey and Deborah Steva of the Ohio Department of Health for assistance with this article.

[1]This listing does not constitute an offical endorsement by the Division of Geological Survey. It is provided only for public information.

FURTHER READING

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RARE ARTHRODIRE JAW FOUND IN COLUMBUS

Important discoveries are not always the result of carefully planned investigations. Instead, there is commonly an element of being in the right place at the right time—some call it luck. And so it was for Preston Fettrow of Columbus last July when he discovered a well-preserved lower jaw of a Late Devonian arthrodire fish, *Dinichthys hertzeri.* This jaw is one of only about half a dozen known specimens of this arthrodire and the first one to be found in central Ohio for more than a century.

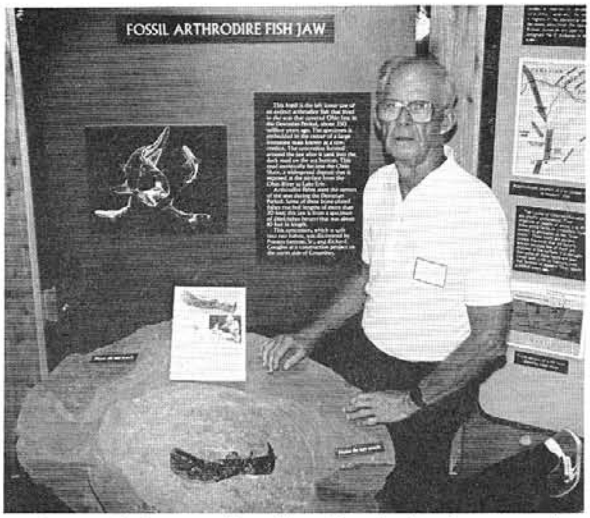
Fettrow has been an active and successful participant in the Survey's annual Ohio Geology Slide Contest and is always on the lookout for interesting, unusual, and photogenic geologic features. This interest led him to explore an excavation in the Ohio Shale for a road to a housing development in north Columbus. This excavation resulted in the uncovering of numerous spherical concretions in the shale that ranged in diameter from a few inches to as large as about 7 feet. Such concretions are typical of the lower portion of the Ohio Shale, known as the Huron Member, and are common yard ornaments throughout central Ohio.

In the course of photographing some of these concretions, Fettrow noticed one about 3½ feet in diameter that had been split in half, exposing a shiny black object in the center of the dark-gray matrix. He brought photographs of this object to the Division of Geological Survey, where it was recognized to be the left lower jaw (technically known as an inferognathal element) of *Dinichthys hertzeri.*

A crew of Survey geologists consisting of Michael C. Hansen, Jack A. Leow, and Joel D. Vormelker accompanied Fettrow to the site in order to recover the jaw before it was lost to construction activities. Through the efforts of the Savco Construction Company and their bulldozer, the 700-pound concretion was loaded into a Division of Geological Survey vehicle and eventually transported to the Natural Resources Area at the Ohio State Fair. The jaw was a featured exhibit during the 17-day run of the 1986 fair.

At the time of discovery of the jaw-bearing concretion, only half of the concretion could be located and it was assumed that the other half was buried and lost during the course of construction activities. A newspaper article about the jaw in the *Columbus Dispatch* prompted a telephone call to the Survey from Richard Googins of Columbus, who indicated that the missing half of the concretion was in his possession. Googins generously donated this other half of the specimen to the Division. The second half is primarily a mold of the jaw bone in the first half of the concretion.

The jaw, which measures 10.5 inches in length, has two spikelike projections toward the front and a cutting blade. The fish from which the jaw was derived probably measured



Preston S. Fettrow, Sr. with arthrodire jaw in concretion at the 1986 Ohio State Fair.

about 5 feet in length. Jaws of this same species, measuring 2 feet in length, were collected from concretions in Delaware County in the 1870's and were described by John Strong Newberry, second State Geologist of Ohio, in an 1873 Ohio Geological Survey report (Volume I, Part II. Palaeontology).

Arthodires were armored fishes that were probably the terrors of Devonian seas. The jaw does not have teeth in the strict sense; however, the bony spikes and cutting blade functioned efficiently in spearing and slicing prey.

Arthrodires, such as *Dinichthys hertzeri*, and a more common species, *Dunkleosteus intermedius*, from the Cleveland Member of the Ohio Shale, belong to a group of fishes characterized by bony plates of armor that covered the head and thorax region. Although this group of fishes prospered during the Devonian, by the end of the period (approximately 350 million years ago) they were extinct. Indeed, the diverse arthrodire assemblage from the Cleveland Member, uppermost portion of the Ohio Shale, represents the last of the arthrodires. The reason for this extinction is obscure. It is probable that sharks, which underwent a tremendous diversification in the late Devonian, were able to outcompete the arthrodires for food. The bony armor of the arthrodires, although protecting them from attack, probably restricted their swimming abilities to an extent that sharks, with their lightweight skeletons of cartilage, could in essence snatch the food out of the mouths of the arthrodires. The extinction of the arthrodires was undoubtedly more complex than this simple scenario; however, competition was probably the key ingredient.

Ohio has long been famous as the source for spectacular remains of arthrodires, and the Cleveland Museum of Natural History has the largest collection of these fishes in the world. Most of the specimens were derived from the Cleveland Member of the Ohio Shale, exposed widely in northeastern Ohio. The remainder of the Ohio Shale, throughout its north-south outcrop belt through the central portion of the state, has produced comparatively few remains of arthrodire fishes. Is this a function of greater abundance of these remains in the Cleveland area or simply a function of more intensive searching for these fossils in northern Ohio? This question cannot be answered directly at this time; however, keen eyes and intense curiosity, as exhibited by Preston Fettrow, are critical to such discoveries.

—Michael C. Hansen

SURVEY STAFF NOTES

Merrianne Hackathorn

Mike Hansen

Merrianne Hackathorn is a geologist and editor for all Survey maps and publications. She came to the Survey in 1973 after completing a B.S. degree in biology and an M.S. degree in geology at Bowling Green State University. Merrianne particularly enjoys the variety involved with editing the diverse subject matter of Survey manuscripts and in working with nearly the entire staff in her editorial duties.

Merrianne is well known at the Survey for her liberal use of a red pencil on manuscripts; however, all Survey authors eventually learn to appreciate her advice, which substantially improves nearly every manuscript. She has saved most of us from a major error at one time or another. Merrianne, a native of Norwalk, Ohio, lives in the Columbus suburb of Worthington with her husband, Dave Buchanan, who is also a geologist. She enjoys music, reading, sewing, travelling, and volleyball as hobbies.

Michael C. Hansen is a geologist and editor of *Ohio Geology*. In addition, he is responsible for public relations aspects of the Survey and handles most matters relating to Ohio earthquakes and paleontology that come to the attention of the Survey.

Mike came to the Survey in 1972 and holds B.S. and M.S. degrees in geology from Ohio University and a Ph.D. in geology from the Ohio State University. His research specialties include Carboniferous rocks, Paleozoic sharks, and the history of geology.

Mike lives in the Columbus suburb of Westerville with his wife and daughter and serves as an officer in the Westerville South Marching Band Boosters Association. His hobbies include gardening, although most of his spare time is devoted to research on fossil sharks.

SURVEY STAFF CHANGES

COMINGS

Mark E. Clary, Assistant Driller, Regional Geology Section.

William R. Dunfee, Assistant Driller, Regional Geology Section.

Suzan E. Jervey, Supervisor, Publications Center.

AND GOINGS

Madge R. Fitak, Supervisor, Publications Center.

Carl L. Hopfinger, Geology Technician, Lake Erie Section, to Transmissions Unlimited, Port Clinton.

Cynthia L. Westbrook, Cartographer, Technical Publications Section.

SURVEY RECEIVES COAL RESEARCH GRANT

David A. Berger, Director of the Ohio Coal Development Office, recently announced that the Division of Geological Survey has been awarded a two-year, $500,000 coal research grant. The grant monies were provided by Issue 1, passed by Ohio voters in November 1985 to promote research necessary to revitalize Ohio's coal industry.

The Survey research will chemically and physically characterize coals from the major producing seams in Ohio, develop coal-washing data, and upgrade evaluations of the remaining coal reserves in the state. Detailed information on the chemical and physical properties of Ohio coals will be needed to evaluate their performance in advanced coal-cleaning technologies, gasification, liquefaction, fluidized-bed combustion, and for the use of coal as a chemical feedstock.

Division of Geological Survey geologists will sample Ohio coal seams in strip mines, underground mines, and in cores drilled by the Division's core-drilling rigs. Those samples will then be subjected to a wide variety of chemical and physical tests and characterized as to their potential washability for removal of pyritic sulfur. These data will provide the basis for research on and implementation of coal-cleaning technologies that are necessary for maximum utilization of Ohio's high-sulfur coals. Survey geologists George Botoman, Richard Carlton, Douglas Crowell, and David Stith and chemist Norman Knapp, along with other Survey staff, will carry out various phases of this project.

QUARTERLY MINERAL SALES, APRIL—MAY—JUNE 1986

Compiled by Sherry L. Weisgarber

Commodity	Tonnage sold this quarter[1]	Number of mines reporting sales[1]	Value of tonnage sold[1] (dollars)
Coal	8,395,594	218	270,887,584
Limestone/dolomite[2]	9,158,516	92[3]	33,589,978
Sand and gravel[2]	8,912,174	200[3]	27,083,682
Salt[2]	883,169	5[4]	8,932,646
Sandstone/conglomerate[2]	507,769	22[3]	6,364,622
Clay[2]	317,402	24[3]	1,878,598
Shale[2]	407,333	19[3]	418,942
Gypsum[2]	30,215	1	287,043
Peat[2]	2,324	3	29,947

[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.

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