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Ohio Geology

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EARTHQUAKES AND SEISMIC RISK IN OHIO

by Michael C. Hansen

In these days of instantaneous electronic communications, most people are aware of the devastation that can be wrought by an earthquake. Images of the terrible destruction in Armenia, where 25,000 people were killed in 1988, or the horrible scenes of the pancaked decks of the Nimitz freeway in Oakland, California, during the 1989 Loma Prieta earthquake are dramatic portrayals of the destructive potential of an earthquake.

In Ohio, and indeed in the eastern United States, there is a perception that destructive earthquakes happen elsewhere but not here. In the short term, there is some truth to this observation, because few people now living have experienced a destructive earthquake in the eastern part of the country. Large eastern earthquakes have such long recurrence intervals that it is almost inevitable that a complacent attitude will develop among the populace. It is human nature, perhaps, to assume that what has not happened for a long time will probably not happen again for a long time.

In his 1992 presidential address to the Seismological Society of America, seismologist Robin K. McGuire stated that ". . . major earthquakes are a low-probability, high-consequence event. . . ." It is because of the potential high consequences that geologists, emergency planners, and other government officials have taken a greater interest in understanding the potential for earthquakes in some areas of the eastern United States and in educating the population as to the risk in their areas. Although there have been great strides in increased earthquake awareness in the east, the low probability of such events makes it difficult to convince most people that they should be prepared.

Toppled chimneys were common in Anna, Ohio, from the March 2 and March 9, 1937, earthquakes. In this home, the chimney crashed through the ceiling, scattering bricks in a bedroom. Miraculously, no serious injuries resulted from these earthquakes.

EARTHQUAKES AND FAULTING IN OHIO

Ohio earthquakes are shallow-focus events, that is, they occur in the upper portion of the crust at depths of about 5 to 10 kilometers in crystalline (igneous and metamorphic) rocks of Precambrian age. In general, Ohio earthquakes appear to occur along faults that define pre-existing zones of weakness in Precambrian rocks. It is thought that favorably oriented faults are periodically reactivated in the current stress regime, which is northeast-southwest compression.

Very few faults in Ohio are visible at the surface and no surface faults in Ohio are known to be associated with historic earthquakes. Furthermore, none of these faults exhibit evidence of movement during Recent (Holocene) time; most of them probably have not been active since the Paleozoic. In fact, surface ruptures by historic earthquakes have not been clearly demonstrated in the eastern United States. Most faults known in Ohio in the subsurface appear to originate in Precambrian rocks and die out upward in the overlying Paleozoic rocks. Therefore, most of them do not reach the surface where they can be directly mapped and studied. Moreover, the bedrock surface in about two-thirds of the state is masked by a thick cover of glacial sediments.

HISTORIC EARTHQUAKE ACTIVITY IN OHIO

At least 120 earthquakes with epicenters in Ohio have been felt since 1776, and 14 of these events are known to have caused minor to moderate damage. Fortunately, there have been no deaths and only a few minor injuries recorded for these events.

Instrumental measurement of Ohio earthquakes began in 1900 at John Carroll University in Cleveland and was followed in 1927 by establishment of a seismograph station at Xavier University in Cincinnati. It was not until the 1960's that modern seismographs became widely available so that most moderate-size earthquakes could be located fairly accurately. From 1977 to 1992, there were between 9 and 14 seismographs in the state. Currently, there are no operating research seismographs in Ohio (see accompanying article). The U.S. Army Corps of Engineers

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

EARTHQUAKE PREDICTION IN OHIO

My heart goes out to the hundreds of thousands of people who have been devastated by the 1,000-year floods of the American Midwest of 1993. I experienced a 500-year flood in 1972 in Pennsylvania. It was an event that I will never forget.

In dealing with natural disasters such as floods, hurricanes, tornados, earthquakes, volcanic eruptions, collapsing sinkholes, and landslides, citizens look to expert scientists to tell them when these events will happen again. The experts have called this year's Midwestern floods a 1,000-year event. I think many average citizens may interpret this designation to mean that a flood of that magnitude will not recur for another thousand years. We need to understand how such designations are made. For floods and most other natural disasters, magnitudes are plotted against recorded frequencies, and a curve is drawn. The record may contain only 100 or 200 years of observations, but a curve is still drawn. When an event occurs that exceeds any previous record, the curve is extrapolated along its trend until it intersects the magnitude of the new event, and a frequency is projected from that point. This is an exercise in statistics that has some validity, but it does not mean that natural disasters will always fit the curve. It is possible that another 1,000-year flood could strike the Mississippi-Missouri River watershed next year. I have heard that during the past several years, a number of 500-year floods have taken place in Texas.

The problem with predicting natural events is that we often do not have enough information to develop a statistically accurate probability curve. This is quite true for earthquakes in Ohio, which is the general theme of this issue of *Ohio Geology*. We have some data for Ohio which were accurately recorded for a number of years by precision seismic equipment. The best data were collected by two seismic nets, one deployed in northeastern Ohio by John Carroll University, and another deployed around the Anna seismic zone in west-central Ohio by the University of Michigan. Geoscientific instrumentation like this records earthquake magnitudes measured on the Richter scale from the smallest tremors to the largest damaging earthquakes. *Sadly, the two nets were dismantled last year due to insufficient funds.*

Another method of measuring earthquake magnitude is to record the observations of people who have experienced such events and classify their observations by the Modified Mercalli Intensity Scale. This approach, albeit somewhat subjective, permits us to build a probability curve covering a longer period of history, including observations made without scientific instruments.

Increasingly, geoscientists are now searching for evidence of prehistoric earthquakes by looking for the "signature" of such events in the sedimentary deposits that are disturbed or faulted by seismic events. One of the most interesting paleoseismic investigations is being carried out by researchers from the U.S. Geological Survey, the Indiana Geological Survey, and Indiana University. They have discovered "sand blows" (earthquake-induced liquefaction features) in the banks of the Wabash River, and have dated them by carbon-14 and archeological methods as being several thousand years old. They have measured the size of the sand blows along the Wabash and its tributaries and have calculated that the epicentral area was near Vincennes, Indiana.

The greatest sequence of earthquakes in historic times in the United States occurred near the town of New Madrid, in the "bootheel" area of southeastern Missouri, during the winter of 1811-1812. During that event, the Mississippi River sporadically reversed its flow in great waves, large segments of the river were relocated miles away, bluffs and homes fell into the raging waters, river boats of all sizes disappeared taking passengers with them, frontier buildings were destroyed, huge fissures opened, sand blows numbered in the thousands, and people hurried to churches and revivals to make amends for their sins. Native Americans reported that fishing lakes in Wisconsin "boiled." Bells rang in Boston and Washington, D.C. In Cincinnati, chimneys fell and brick walls burst or collapsed. Frontier settlers in the Chillicothe and Circleville region ran in panic from their log cabins in the middle of the freezing winter night.

No one can predict exactly when a New Madrid event will recur. The prediction of a December 2, 1990, recurrence by Iben Browning was not supported by the geologic community, but public reactions were unthinkably costly. *No one can provide early warning systems like those used for tornados. But seismic events in Ohio and the Midwest will recur.* Prediction of these events requires a substantial record of instrumental observations—even of the smallest tremors. The ability to predict also requires collection of geologic evidence for prehistoric earthquakes. Investigations like those along the Wabash River by the Indiana researchers need to be conducted in Ohio.

The great 1811-1812 New Madrid earthquakes and the long history of lesser seismic events in the same area are attributed to a deep crustal feature called the Reelfoot rift. Ohio, Indiana, and Kentucky have a somewhat similar deep crustal feature called the East Continent Rift Basin (see Ohio Geological Survey Information Circular 57). This newly discovered basement structure has a tight clustering of Precambrian wrench faults near the Anna, Ohio, seismic zone. Knowing that Ohio has deep crustal features similar to the New Madrid, Missouri, area and knowing that the 1811-1812 event affected Ohio are a considerable concern for me. I cannot predict when a sizable Midcontinent earthquake will shake Ohio. But I can strongly recommend that *now is the time* to: (1) invest in development of a statewide seismic instrument net to collect accurate data for analysis; and (2) invest in studies of prehistoric earthquakes in Ohio. *Now is the time* to utilize good, solid, geoscientific data in the business of prediction. *Now is the time* to bring together geologists, seismologists, state and local disaster planning officials, and state policy-makers to consider the potential for large earthquakes. The Ohio Seismic Hazards Advisory Board established by Governor Voinovich has made a beginning by considering various approaches for establishing a seismic net in Ohio.

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EARTHQUAKE MATERIALS FOR TEACHERS

The Seismological Society of America has prepared a list of resources on earthquakes that include videotapes, reference information, and computer-related items that will be of interest to teachers who include discussions of earthquakes in their classes. This information, titled *Seismology: resources for teachers*, is available at no charge from:

Seismological Society of America
201 Plaza Professional Building
El Cerrito, California 94530-4003.

Please include a self-addressed, stamped envelope when ordering the listing.

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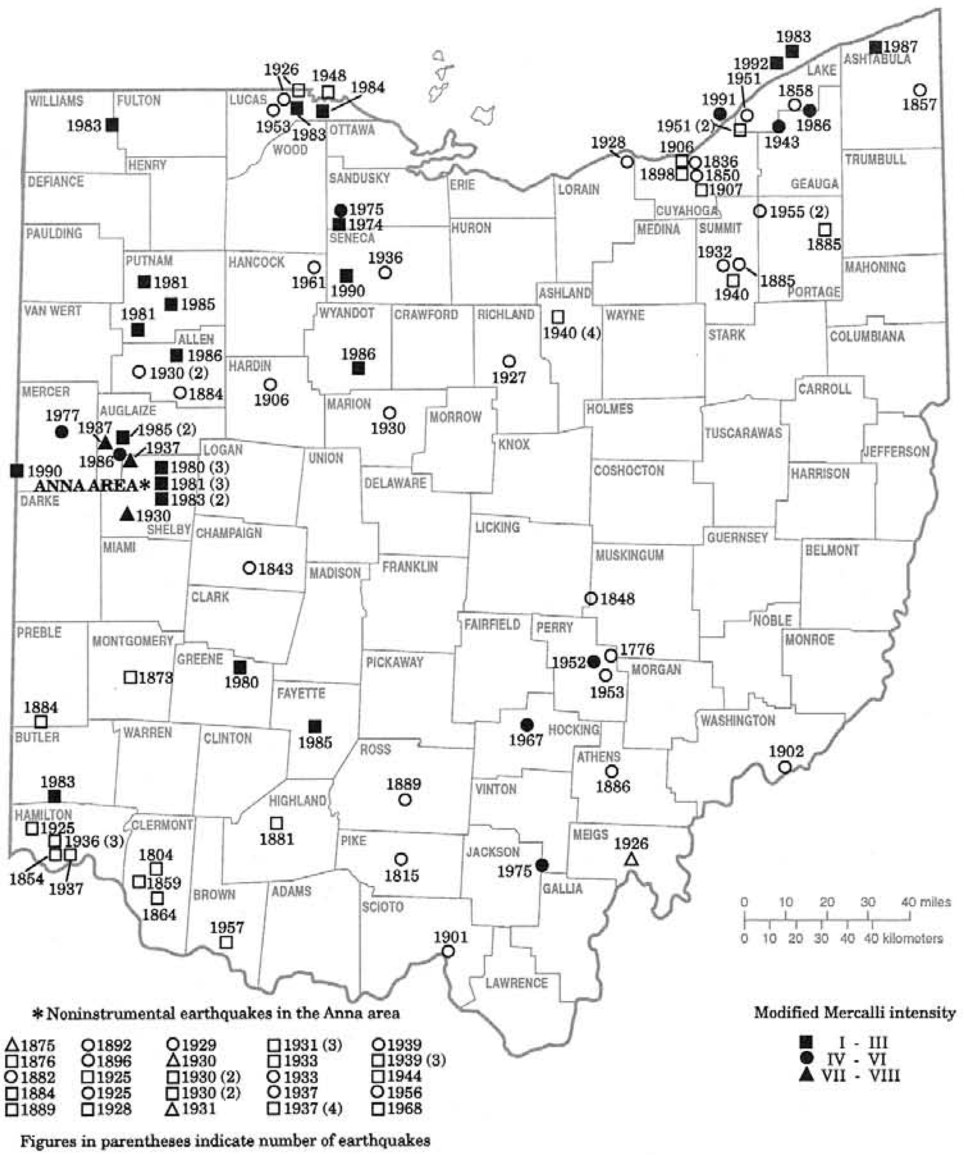


Earthquake epicenters in Ohio. Locations and intensities of historic earthquakes in Ohio are represented by symbols corresponding to maximum epicentral Modified Mercalli intensities. Solid symbols indicate the event was located by instruments. Noninstrumental locations may be in error by a considerable distance, especially for early events.

maintains a strong-motion accelerograph at Michael J. Kirwan Dam in Portage County. This instrument records ground motion and is triggered when acceleration from a nearby earthquake reaches 0.01g.

Most earthquakes that occurred in Ohio before the 1960's have been located and assigned intensities based on newspaper accounts. It is probable that epicentral locations for many of these events may have a considerable margin of error and intensities may be off by one or more levels. Noninstrumental data should be used cautiously until these events can be re-evaluated.

Seismic activity is concentrated in, but not confined to, three areas of the state. Shelby and Auglaize Counties and portions of some adjacent counties in western Ohio (known as the western Ohio seismic zone) constitute the most active seismic area. At least 40 felt earthquakes have occurred there since 1875. Although most of these events have caused little or no damage, earthquakes in 1875, 1930, 1931, 1937, 1977, and 1986 caused minor to moderate damage. Earthquake damage has been most severe in the Shelby County community of Anna. This town is centered over a 400-foot-deep buried valley that was formed in preglacial time by the Teays River. It is thought that Anna has experienced comparatively severe ground motion because of amplification of seismic waves by this thick valley fill. The western Ohio seismic zone appears to coincide with a series of northwest-southeast-oriented faults that are interpreted to be part of a rift zone known as the Anna or Fort Wayne rift.

Northeastern Ohio has experienced at least 20 felt earthquakes since 1836; most have been small and caused little or no damage. A magnitude 4.5 event occurred in 1943 and a magnitude 5.0 event occurred in 1986; the latter event caused minor damage and several injuries (see *Ohio Geology*, Summer 1986). Some geologists have suggested that some of these earthquakes occurred on an extensive north-south linear feature in Precambrian basement rocks known as the Akron Magnetic Lineament.

Southeastern Ohio has been the epicentral location for at least 10 felt earthquakes since 1776. Events in 1776 (location uncertain), in 1901 near Portsmouth, 1926 near Pomeroy, and 1952 near Crooksville caused minor to moderate damage. The geologic sources for these events are poorly understood.

Small earthquakes have been scattered through other portions of the state, particularly in southwestern Ohio in the vicinity of Cincinnati and in northwestern Ohio, including the Toledo area. Central and east-central Ohio are the only areas of the state that have not been the site of earthquakes in historic times.

	Modified Mercalli Scale	Richter Magnitude Scale
I	Detected only by sensitive instruments	1.5
II	Felt by few persons at rest, especially on upper floors; delicately suspended objects may swing	2
III	Felt noticeably indoors, but not always recognized as earthquake; standing autos rock slightly, vibrations like passing truck	2.5
IV	Felt indoors by many, outdoors by few, at night some awaken; dishes, windows, doors disturbed; standing autos rock noticeably	3
V	Felt by most people; some breakage of dishes, windows, and plaster; disturbance of tall objects	3.5 4
VI	Felt by all, many frightened and run outdoors; falling plaster and chimneys, damage small	4.5
VII	Everybody runs outdoors; damage to buildings varies depending on quality of construction; noticed by drivers of autos	5
VIII	Panel walls thrown out of frames; walls, monuments, chimneys fall; sand and mud ejected; drivers of autos disturbed	5.5
IX	Buildings shifted off foundations, cracked, thrown out of plumb; ground cracked; underground pipes broken	6 6.5
X	Most masonry and frame structures destroyed; ground cracked, rails bent, landslides	7
XI	Few structures remain standing; bridges destroyed, fissures in ground, pipes broken, landslides, rails bent	7.5
XII	Damage total; waves seen on ground surface, lines of sight and level distorted, objects thrown up into air	8

General relationship between epicentral Modified Mercalli intensities and Richter magnitude. Intensities can be highly variable, depending on local geologic conditions (modified from D.W. Steeples, 1978, Earthquakes: Kansas Geological Survey pamphlet).

Numerous earthquakes with epicenters in other states have been felt in Ohio, and at least two of them have caused damage. The 1811-1812 series of earthquakes at New Madrid, Missouri, the largest earthquakes in historic times in the continental United States, were felt strongly throughout Ohio and were reported to have knocked down chimneys in Cincinnati. It has been estimated that Modified Mercalli intensities (MMI) of VII to VIII were achieved in southwestern Ohio during these events. An earthquake with a magnitude of 5.3 centered at Sharpsburg, Kentucky, in 1980 was strongly felt throughout Ohio and caused minor to moderate damage in some communities near the Ohio River in southwestern Ohio.

SIGNIFICANT OHIO EARTHQUAKES

Summer 1776: The earliest Ohio earthquake to be recorded occurred at 8:00 a.m. sometime in the summer of 1776 and was chronicled by John Heckewelder, a Moravian missionary, who reported that "the southwest side of the house was raised with such violence that the furniture of the room was nearly overturned." Heckewelder spent the summer of 1776 at the Moravian mission of Lichtenau, which was in present-day Coshocton County. Because this is the only account of this event, it is impossible to determine an epicentral location with any certainty. Indeed, the epicenter of this earthquake may not have been in Ohio.

February 13, 1779: Another early earthquake that was felt in Ohio was on the morning of February 13, 1779, and was noted by another Moravian missionary residing at Lichtenau, David Zeisberger. Zeisberger's diary (preserved in the Moravian Archives at Bethlehem, Pennsylvania) states for the above date (translation by Vernon H. Nelson, Moravian Archives): "On the 13th before noon an earthquake was felt here and in all the places at the same time where our brothers and sisters were in the forest in their sugar huts. We heard later from the Shawnee—Mingo—Wyandot warriors that it was felt in their widely separated places at the same time." The reports by the various tribes suggest that this event was felt throughout Ohio because the Mingos lived in the upper Ohio Valley (Jefferson County and adjacent areas), the Shawnees were in the Scioto Valley and westward, and the Wyandots were in north-central and northwestern Ohio. Most earthquake catalogs place the epicenter of this event in Kentucky, but that location must be considered suspect until additional data can be located.

1811 and 1812: On December 16, 1811, and January 23 and February 7, 1812, the largest earthquakes ever to strike the continental United States occurred at New Madrid, Missouri. These events were felt throughout an area of about 2 million square miles, including all of Ohio. In Ohio, some chimneys were toppled in the Cincinnati area, which experienced the strongest shaking from these events. Should earthquakes of this intensity be repeated, they would probably cause considerable damage in southwestern Ohio.

June 18, 1875: This earthquake was felt throughout an area of at least 40,000 square miles and was most intense at Sidney (Shelby County) and Urbana (Champaign County), where masonry walls were cracked and chimneys toppled. It has been interpreted to have had an MMI of VII.

September 19, 1884: An earthquake in the vicinity of Lima, Allen County, had an epicentral MMI of VI. There were reports of fallen ceiling plaster as far away as Zanesville and Parkersburg, West Virginia. On the basis of a felt area of more than 140,000 square miles, this earthquake is estimated to have had a magnitude of 4.8. Workmen on top of the Washington Monument in Washington, D.C., reported feeling this earthquake.

May 17, 1901: Bricks were dislodged from chimneys and some windows were cracked in Portsmouth, Scioto County, and chimneys were damaged in Sciotoville. Modified Mercalli intensities of VI were generated in the epicentral area. A magnitude of 4.2, based on felt area, has been assigned to this earthquake.

November 5, 1926: This earthquake was centered near Pomeroy and Keno, Meigs County, where chimneys were toppled. A stove was overturned at Chester. Modified Mercalli intensities of VII were generated in the epicentral area, but the earthquake was apparently felt only in portions of Meigs County and adjacent parts of West Virginia. On the basis of this small felt area, this event has been assigned a magnitude of 3.8. Explosive earth sounds were reported to have accompanied this earthquake.

September 30, 1930: Plaster was cracked and a chimney toppled in Anna, Shelby County. An epicentral MMI of VII and a magnitude of 4.2 have been assigned to this event.

September 20, 1931: Anna and Sidney in Shelby County experienced toppled chimneys and cracked plaster. Store merchandise and crockery were knocked off shelves and stones were jarred loose from the foundation of the Lutheran church in Anna. A ceiling collapsed in a school at Botkins, north of Anna. An MMI of VII and a magnitude of 4.7 have been assigned to this earthquake.

March 2 and 9, 1937: These two earthquakes are the most damaging to strike Ohio. Maximum intensities were experienced at Anna, Shelby County, where MMI VII was associated with the March 2 event and MMI VIII with the March 9 event. In Anna, chimneys were toppled, organ pipes were twisted in the Lutheran church, the masonry school building was so badly cracked that it was razed, water wells were disturbed, and cemetery monuments were rotated. Both earthquakes were felt throughout a multistate area—plaster was cracked as far away as Fort Wayne, Indiana. The March 9 event was felt throughout an area of about 150,000 square miles. Recent analysis of seismograms from these earthquakes by the U.S. Geological Survey assigned magnitudes of 4.7 and 4.9, respectively, to these events. Based on felt area, these earthquakes have been assigned magnitudes of 5.0 and 5.5, respectively.

January 31, 1986: This earthquake, which had a magnitude of 5.0 and MMI in the high VI range, occurred in Lake County, east of Cleveland, in the general vicinity of a magnitude 4.5 event in 1943. The 1986 earthquake cracked plaster and masonry, broke windows, and caused changes in water wells. The epicenter was only a few miles from the Perry nuclear power plant. It is the most intensively studied earthquake in Ohio and was the subject of several reports (see *Ohio Geology*, Summer 1986).

July 12, 1986: Minor damages, consisting primarily of cracked windows and plaster and fallen bricks from chimneys, were reported from this Modified Mercalli intensity VI earthquake centered northwest of Anna, near St. Marys, Auglaize County. It was assigned a magnitude of 4.6.

SEISMIC HAZARD IN OHIO

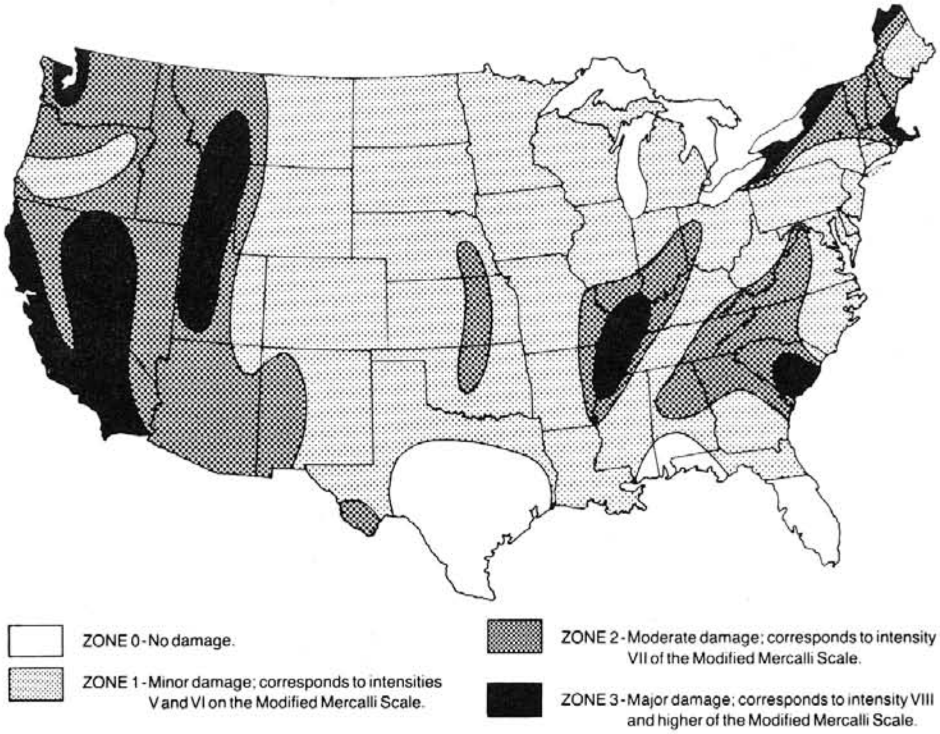
Seismic hazard refers to the probability that earthquake phenomena, such as ground shaking, that may result in damage or loss of life will occur in an area within a specified period of time. In evaluating the seismic hazard of an area, consideration must be given to geologic factors such as susceptibility to increased ground motion on unconsolidated sediments, landslides, and the potential for liquefaction—a phenomenon in which normally solid sediments become liquified and lose bearing strength during an earthquake.

Historic earthquake activity is an important part of the process of determining Ohio's seismic hazard. It must be kept in mind that our 200-year history of earthquake activity in Ohio is just an instant geologically. Earthquakes in Ohio and, indeed the eastern United States, tend to have long recurrence intervals, that is, it may be hundreds, or even thousands, of years between large, damaging earthquakes. For example, had the 1811-1812 series of earthquakes at New Madrid, Missouri, occurred a century or two earlier, it is unlikely that we would currently perceive this area as capable of generating such large earthquakes.

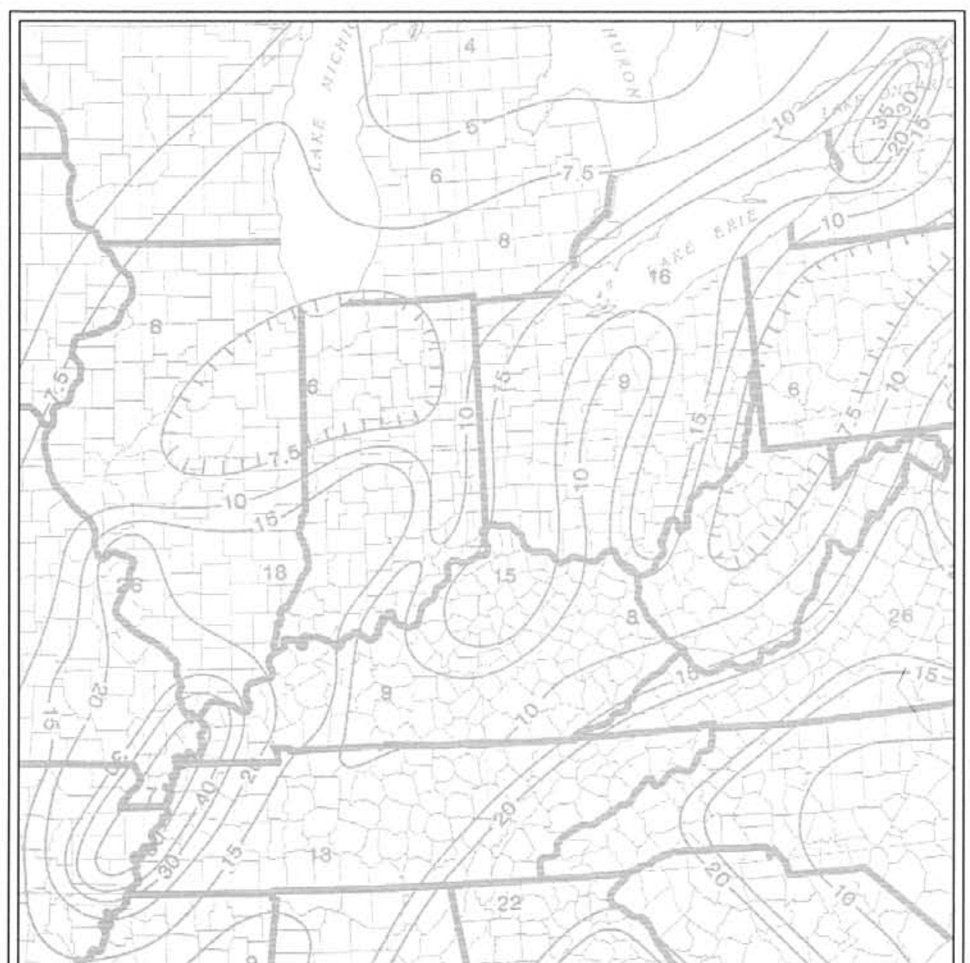
The brief historic record of earthquakes in Ohio would suggest that a magnitude 5 earthquake is about the maximum event for the state. However, there is some concern that earthquakes in the magnitude 6 range could occur periodically. On the basis of available data, it is difficult to accurately predict the maximum-size earthquake that could occur in the state and certainly impossible to predict when such an event would occur. In part, the size of an earthquake is a function of the area of a fault available for rupture. However, because all known earthquake-generating faults in Ohio are concealed beneath several thousand feet of Paleozoic sedimentary rock, it is difficult to directly determine the size of these faults.

On the basis of historic seismic activity, it is likely that large earthquakes with epicenters in the state would occur in the western Ohio seismic zone or in northeastern Ohio, with a lesser possibility in southeastern Ohio. Some researchers have suggested that northeastern Ohio is capable of a maximum 6.5 magnitude earthquake, whereas western Ohio may be capable of producing an event in the 6.0 to 7.0 magnitude range (maximum MMI of IX). These suggestions are speculations at best, because there are inadequate data available to accurately judge the extent of the area available for rupture on any earthquake-generating fault.

There are several earthquake risk maps in wide use in the United States. Perhaps the most widely used map was produced in 1969 by the U.S. Geological Survey. This map is based on historic earthquake activity and seismic source zones and divides areas of the country into zones ranging from zone 0—no damage expected—to zone 3—major damage expected. Most of Ohio is in zone 1—minor damage, MMI V to VI; western Ohio and part of northeastern Ohio are in zone 2—moderate damage, MMI VII. Although this map is a useful generalization of seismic risk in Ohio, it does not incorporate new knowledge of potential earthquake-generating structures in Ohio's basement rocks and a probable greater earthquake risk in northeastern Ohio. Such maps use



Seismic risk map of the United States. This widely used map is deterministic, that is, risk zones are based on historic damaging earthquake activity (from Algermissen, 1969).



Map of horizontal acceleration (expressed as a percent of gravity) in rock with a 90 percent probability of not being exceeded in 250 years. The acceleration of gravity is expressed as 1g. The "10" contour represents an acceleration of 10 percent of gravity, or 0.1g (from Algermissen and others, 1990).

lines to separate zones, whereas in reality zone boundaries are gradational.

Another widely used U.S. Geological Survey map is based upon observations and inferences of the probable maximum ground motion, not to be exceeded within a specified period of time (commonly 50 to 250 years). These maps depict horizontal acceleration expressed as a percent of gravity and are particularly useful to engineers, architects, and insurance actuaries.

Acceleration is the rate of change of motion as the Earth's surface moves back and forth during an earthquake (ground shaking). The acceleration due to gravity is 32 feet per second squared (980 centimeters per second squared), which is commonly expressed as 1.0g. At an acceleration rate of 0.1g, some damage may occur in poorly constructed buildings. Between 0.1g and 0.2g, most people begin to have difficulty in keeping their footing and may experience nausea. New acceleration maps being developed by the U.S. Geological Survey incorporate spectral response at 0.3 and 1.0 second, which are commonly used figures in designing low-rise and high-rise buildings, respectively. These maps allow engineers and architects to design buildings to withstand maximum probable accelerations in a specified area.

RANGES OF ACCELERATION AS A FUNCTION OF INTENSITY
(adapted from Bolt, 1975)

MM intensity	*Range of acceleration (g's)*
VI	0.005 - 0.065
VII	0.010 - 0.20
VIII	0.025 - 0.35
IX	0.05 - 0.90
X	0.10 - 1.0+

Note: 1g = 980 cm/sec²

Acceleration is a prime component in maps prepared by the Building Official Code Administration International (BOCA). In Ohio, these maps are used in designing new commercial buildings and structures housing more than four families. Regulations for seismic considerations in new construction are uniformly applied statewide by the Board of Building Standards of the Ohio Department of Industrial Relations.

In large objects with a great mass, such as a building, ground motion, particularly horizontal motion, can produce tremendous forces that can seriously damage a structure if the duration of the shaking lasts for a comparatively long period of time. During many earthquakes, the destructive shaking only lasts for about 10 seconds. Some very destructive earthquakes generate severe shaking for a minute or more. The 1986 northeastern Ohio earthquake generated accelerations as high as 0.19g to 0.23g; however, these were momentary peak accelerations of such short duration that they did not cause significant damage.

National seismic-risk maps are greatly generalized and intended to depict these risks on a broad scale. Ideally, detailed seismic-risk maps should be produced for areas of the state that have historic seismic activity. Such maps include critical analysis of historic earthquakes, detailed mapping of bedrock, structural, and surficial geology, investigation of prehistoric earthquake (paleoseismic) activity, and analysis of soils and their engineering characteristics.

OHIO SEISMIC HAZARDS ADVISORY BOARD

In 1991, Governor George V. Voinovich issued Executive Order 91-13V establishing the Ohio Seismic Hazards Advisory Board. The 11-member board meets quarterly and serves in an advisory capacity to the Governor. Members represent various state agencies, academia, and private research. Thomas M. Berg, Chief of the Division of Geological Survey, and Dale W. Shipley, Deputy Director of the Ohio Emergency Management Agency, serve as co-chairmen of the board.

The Ohio Seismic Hazards Advisory Board has devoted most of its efforts to addressing the demise of seismic monitoring in the state (see accompanying article) and has explored various possibilities to establish and fund a statewide network of seismographs. The board will address other aspects of seismic risk in future meetings.

The State of Ohio recently became an associate member of the Central United States Earthquake Consortium (CUSEC), an organization formed by the emergency management agencies of the seven states bordering the New Madrid seismic zone (members) or peripheral states that would be affected during a large earthquake at New Madrid (associate members). The states geologists of CUSEC states have formed an advisory committee to address geologic factors associated with earthquake risk in the central United States.

ACKNOWLEDGMENTS

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FURTHER READING

Algermissen, S. T., 1969, Seismic risk studies in the United States: Proceedings of the 4th World Conference on Earthquake Engineering, Santiago, Chile, v. 1, 14 p.

Algermissen, S. T., and Hopper, M. G., 1985, Estimated maximum regional seismic intensities associated with an ensemble of great earthquakes that might occur along the New Madrid seismic zone: U.S. Geological Survey Miscellaneous Field Studies Map MF-1712.

Algermissen, S. T., Perkins, D. M., Thenhaus, P. C., Hanson, S. L., and Bender, B. L., 1990, Probabilistic earthquake acceleration and velocity maps for the United States and Puerto Rico: U.S. Geological Survey Miscellaneous Field Studies Map MF-2120.

Bolt, B. A., 1975, Earthquakes: San Francisco, W. H. Freeman and Company, 282 p. (a second edition was published in 1988).

Hansen, M. C., 1975, Earthquakes in Ohio: Ohio Division of Geological Survey Educational Leaflet 9.

Nicholson, Craig, Roeloffs, E., and Wesson, R. L., 1988, The northeastern Ohio earthquake of 31 January 1986: was it induced?: Bulletin of the Seismological Society of America, v. 78, p. 188-217.

Stover, C. W., 1987, Seismicity map of Ohio: U.S. Geological Survey Miscellaneous Field Studies Map MF-1975.

Stover, C. W., and Coffman, J. L., 1993, Seismicity of the United States, 1568-1989 (revised): U.S. Geological Survey Professional Paper 1527, 418 p.

NEW GUIDEBOOKS ON OHIO GEOLOGY

The Division of Geological Survey has recently issued several guidebooks on Ohio geology that were prepared for the national Geological Society of America meeting, held in October 1992 in Cincinnati. Several additional guidebooks are in preparation for printing and will be announced in a future issue of *Ohio Geology*. Mail orders should include handling charges and 5.75 percent Ohio sales tax if mailed to an Ohio address.

Guidebook 5, *Guide to the building stones of downtown Cleveland: a walking tour*, by Joseph T. Hannibal and Mark T. Schmidt, 33 p., 33 figs., 3 tables, $3.50.

Guidebook 7, *Guide to the building stones of downtown Cincinnati: a walking tour*, by Joseph T. Hannibal and Richard Arnold Davis, 44 p., 39 figs., 3 tables, $3.50.

Guidebook 8, *Geologic glimpses from around the world—the geology of monuments in Woodland Cemetery and Arboretum, Dayton, Ohio: a self-guided tour*, by Michael R. Sandy, 29 p., 10 figs., 1 table, 6 pls. (including 2 in full color), $4.00.

Guidebook 9, *Cincinnati's geologic environment: a trip for secondary-school science teachers*, by William C. Haneberg, Mary M. Riestenberg, Richard E. Pohana, and Sharon C. Diekmeyer, 23 p., 24 figs., $3.00.

Guidebook 12, *Excursion to Caesar Creek State Park in Warren County, Ohio: a classic Upper Ordovician fossil-collecting locality*, by Douglas L. Shrake, 18 p., 11 figs., 9 pls., $3.00.

OHIO SEISMIC NETWORKS DISMANTLED

Since September 1992, Ohio has had no capability to monitor seismic activity in the state. At that time, the University of Michigan began dismantling their nine-station western Ohio network because of lack of continued funding from the Nuclear Regulatory Commission. In the summer of 1992, the five-station northeastern Ohio network, installed after the 1986 Painesville earthquake, and the Seismological Observatory operated by John Carroll University in Cleveland were closed.

More than 200 local earthquakes, most of them too small to be felt, were recorded by the John Carroll University network between 1986 and 1992. This network was beginning to establish baseline data for northeastern Ohio seismicity and was an important link in monitoring seismicity postulated by some to be associated with injection wells in the area. The network was able to precisely locate many northeastern Ohio earthquakes, even very small ones.

The John Carroll University collection of seismograms, which date from the early 1940's, was transferred to the Division of Geological Survey. The Survey will maintain these records until a more suitable repository can be found. Requests for copies of specific records should be directed to the Survey.

The demise of the John Carroll University Seismological Observatory brings an end to nearly a century of seismic investigations at this institution, which was the flagship of the Jesuit Seismological Service. In 1893, Rev. Frederick L. Odenbach, S.J., was assigned to St. Ignatius College (later named John Carroll University) in Cleveland, where he began to pursue his interests in science, particularly meteorology. In 1900, Father Odenbach built his first seismograph and began to organize a cooperative effort in seismic recording at Jesuit institutions in the United States and Canada. By 1911, there were 16 participating institutions. In 1925, Xavier University in Cincinnati joined the network. This station operated until the early 1970's.

Father Odenbach maintained an active program of seismic recording until his death in 1933. He was succeeded by Rev. Joseph S. Joliat, S.J., who was director of the observatory until 1947, when Rev. Henry F. Birkenhauer, S.J., became director. Dr. Edward J. Walter, who was Father Birkenhauer's assistant, assumed the directorship in 1962 and held this position until his retirement in 1984, when Rev. William Ott, S.J., became director. The observatory closed when Father Ott moved to Bolivia.

The Anna network in western Ohio was established in 1977 in order to monitor seismicity because of historic seismic activity in this area (most notably in 1937) and because of the proximity of the region to several nuclear power plants. Nearly 50 events were located in the Anna area between 1977 and 1992. The Seismological Observatory of the Department of Geological Sciences at The University of Michigan installed a nine-station network in western Ohio, four stations in adjoining portions of Indiana, and two stations in Michigan. Funding for this network was withdrawn in anticipation of the installation of a National Seismic Network by the U.S. Geological Survey.

A National Network station is scheduled for installation in Ohio in 1994 as part of the U.S. National Seismic Network (USNSN). Although this sophisticated station, which will use satellite telemetry to relay signals to the National Earthquake Information Center in Colorado, will provide coverage in Ohio, it will only be able to locate events that are about Richter magnitude 2.5 or larger, and will have a margin of locational error of several kilometers. The USNSN station is a welcome addition to Ohio, but it cannot replace the western Ohio and northeastern Ohio networks, which had the capability to locate very small earthquakes with considerable precision and thus add to our knowledge of the state's deep structures and seismic source zones.

The closing of the John Carroll observatory brings to an end a long history of seismic monitoring in the state at Jesuit institutions, and the closing of the Anna network ends a 15-year record of baseline data in the state's most seismically active area. Perhaps more importantly, the closing of these networks leaves a significant gap in our ability to precisely locate and study seismic activity and deep structures in the state at a time when public awareness of earthquake potential in Ohio and in the Midwest has reached a high level.

—Michael C. Hansen

FURTHER READING

Macelwane, J. B., editor, 1950, Jesuit Seismological Association, 1925-1950: St. Louis University, 347 p.

Finan, Valerie, 1991, Present at the creation [story of Father Odenbach]: Carroll Alumni Journal, August, p. 1, 11-12.

OHIO PARKS AND NATURAL RESOURCES FUND

The Ohio Parks and Natural Resources Bond Issue (State Issue #1), proposed by Governor George V. Voinovich and endorsed by a bipartisan majority of the Ohio General Assembly, will go to Ohio voters for approval on November 2. If passed, Issue #1 will provide funds for the maintenance, preservation, and improvement of Ohio's state and local parks, recreational facilities, and natural resources infrastructure. More than half of funds allocated from the bond issue will be used to rehabilitate and upgrade Ohio's state and local parks system. Additional funds will be used for environmentally critical projects at other Ohio Department of Natural Resources facilities, including state forests, nature preserves, and wildlife areas. The Division of Geological Survey would benefit greatly from Issue #1, which would provide monies to build a Division-owned core and sample repository in Columbus as well as an office and equipment-storage facility for the Lake Erie Geology Section in Sandusky. In the long term, construction of these facilities would result in considerable savings to the Division and the State because these needs are currently being met with leased buildings. If approved by voters, Issue #1 bonds would be retired through the State's existing tax revenues. Issue #1 is not a tax or levy, nor does it increases taxes. The Division of Geological Survey welcomes your comments or questions on this important issue.

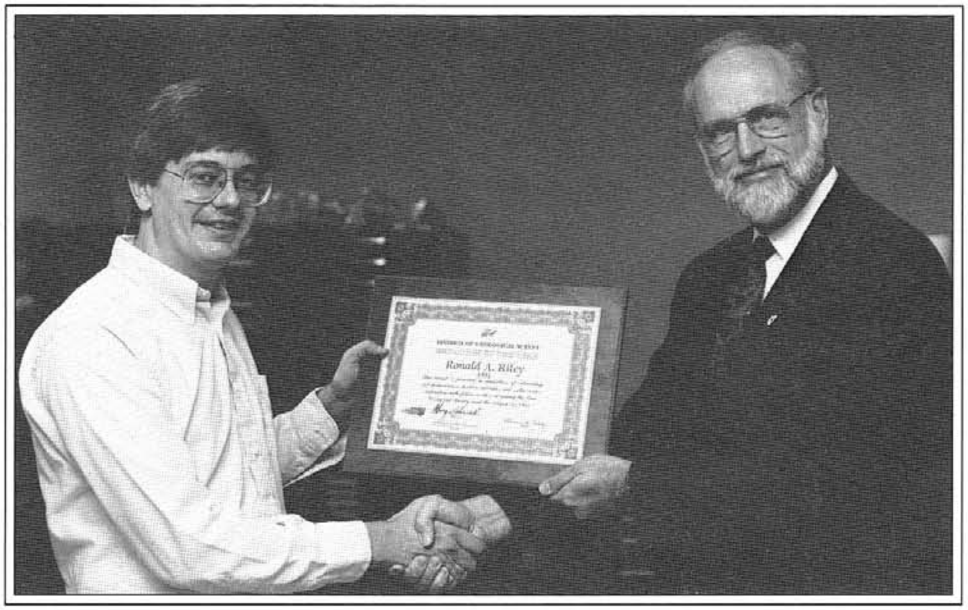
KNOX UNCONFORMITY MAPS AVAILABLE

The Division of Geological Survey has completed two structure-contour maps of the Knox unconformity in southeastern and northeastern Ohio as part of U.S. Department of Energy-funded research on the Rose Run sandstone. These maps are at a scale of 1:250,000 and a contour interval of 100 feet. The open-file maps are part of the Survey's Digital Map and Chart Series and are designated as DCMS-8 (southeastern Ohio) and DCMS-9 (northeastern Ohio). Copies of these maps are available from the Survey for $10.00 each, plus $0.58 Ohio sales tax and $3.00 handling for one map or $1.15 Ohio sales tax and $5.00 handling for both maps.

CONFERENCE ON WASTE MANAGEMENT AND REDUCTION

A summit conference on waste reduction, recycling, and the future of solid-waste management in Ohio will be held November 8-10, 1993, at the Seagate Center in Toledo. The conference is sponsored by numerous professional, industry, and nonprofit organizations that are involved with various aspects of waste management and recycling. For additional information on programming, registration, and exhibition, please contact Resource Ohio '93 at 614-363-0899.

1992 EMPLOYEE OF THE YEAR



Ron Riley, left, receives Employee of the Year Award from Division Chief Thomas M. Berg.

Ronald A. Riley, a geologist in the Subsurface Stratigraphy and Petroleum Geology Section, was named the Employee of the Year for the Survey in 1992. The award plaque was presented to Ron by State Geologist and Division Chief Thomas M. Berg during ceremonies at the Survey's annual Christmas luncheon. This award is especially coveted because the selection is made by a committee from nominations submitted by Survey employees.

Ron was chosen because of his significant efforts on a U.S. Department of Energy grant to study the Rose Run sandstone, a Cambrian unit that has become a major drilling target for Ohio's oil and gas industry. Ron spent many long hours, often far into the night, completing this project. His dedication and determination have been a positive example to other Survey staff.

Ron joined the Survey in 1985 after five years in petroleum exploration in Tulsa, Oklahoma, and Denver, Colorado. He is a native Ohioan, originally from West Carrollton, and received a bachelor's degree in geology from Miami University and a master's in geology from Bowling Green State University. Prior to the Rose Run project, Ron devoted much of his time to study of Devonian shales in Ohio as part of a project funded by the Gas Research Institute.

Ron is a resident of Columbus and enjoys a variety of sports including fishing, snow skiing, tennis, and volleyball. With the conclusion of the Rose Run project, Ron hopes to have more time to pursue these interests.

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