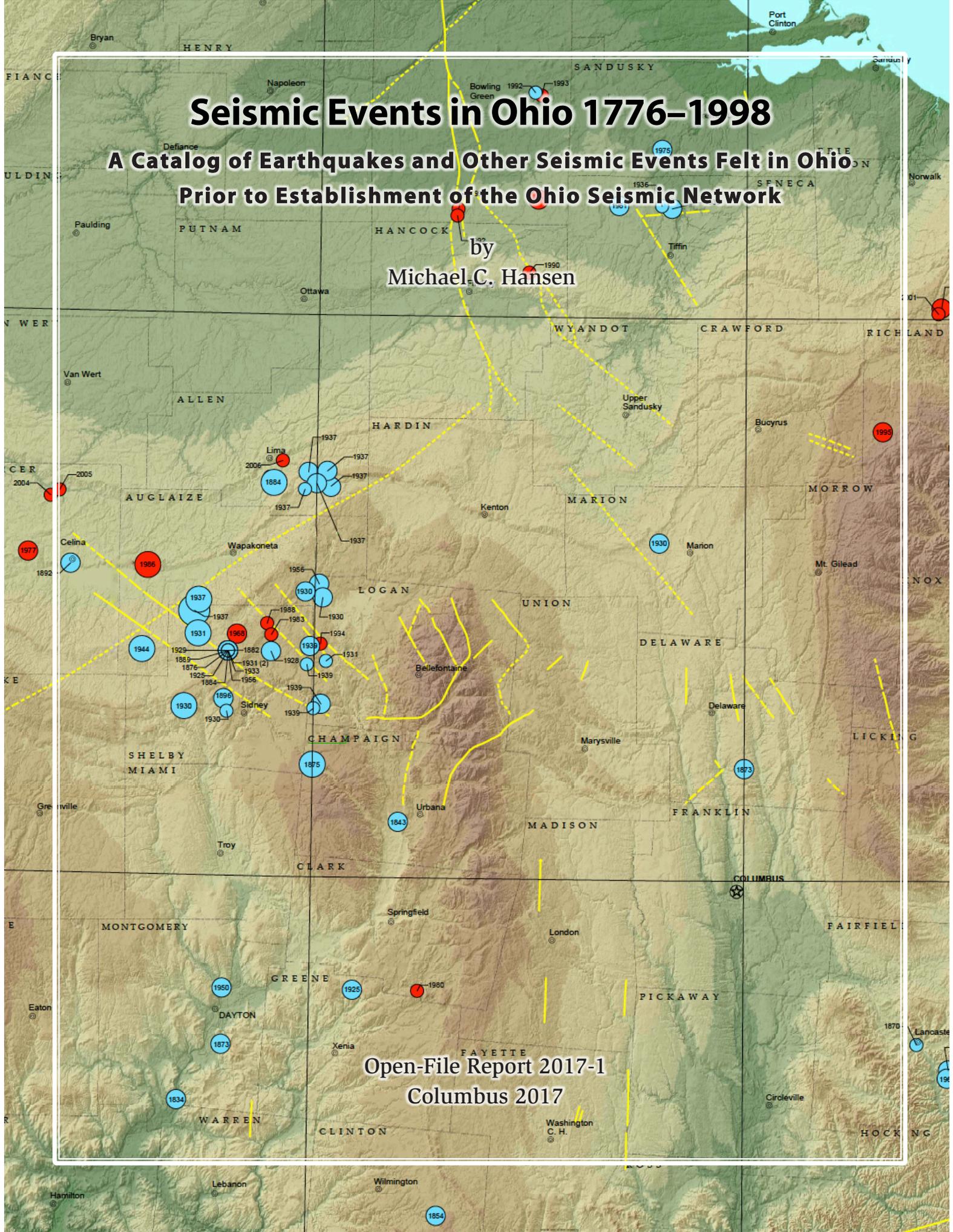


# Seismic Events in Ohio 1776–1998

A Catalog of Earthquakes and Other Seismic Events Felt in Ohio  
Prior to Establishment of the Ohio Seismic Network

by  
Michael C. Hansen

Open-File Report 2017-1  
Columbus 2017





# OhioSeis

The Ohio Seismic Network

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*Cover image:* Northwestern Ohio portion of Map EG-2: Earthquake Epicenters in Ohio and Adjacent Areas (Hansen, 2014).

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# CONTENTS

Introduction .....	1
Previous work .....	1
Acknowledgments .....	3
References cited .....	3
Annotated catalog of earthquakes in Ohio and adjacent areas.....	8
Earthquakes in Ohio of 2.0 magnitude or greater.....	8
Border region earthquakes.....	40
Events of nonseismic origin or doubtful earthquakes.....	53
Introduction.....	53
Mining activities and natural explosions .....	53
Nonseismic earth movements.....	53
Atmospheric events.....	55

# TABLE

1 Comparison chart of seismic magnitude and intensity scales.....	3
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# ABBREVIATIONS USED IN THIS REPORT

## *Units of Measure*

g	acceleration of gravity (1 g=980 cm/sec <sup>2</sup> )
cm	centimeter(s)
m	meter(s)
m <sup>2</sup>	square meter(s)
km	kilometer(s)
km <sup>2</sup>	square kilometer(s)
M	magnitude
mbLg	magnitude scale based on the maximum amplitude of the Lg wave versus distance
mi	mile(s)
MMI	Modified Mercalli Intensity
sq. mi.	square mile(s)
sec	second(s)
lbs	pound(s)

## *Other*

CERI	Center for Earthquake Research and Information
PDE	Preliminary Determination of Epicenters (from USGS)
EDT	Eastern Daylight Time
EST	Eastern Standard Time
lat	latitude
long	longitude
NCE	National Center for Earthquake Engineering Research (NCEER, now MCEER, Multidisciplinary Center for Earthquake Engineering Research)
USGS	U.S. Geological Survey
UTC	Universal Coordinated Time
UTLO	OhioSeis Station at Toledo
VTSO	Virginia Tech Seismological Observatory



# Seismic Events in Ohio 1776–1998

## A Catalog of Earthquakes and Other Seismic Events Felt in Ohio Prior to Establishment of the Ohio Seismic Network

by Michael C. Hansen

### INTRODUCTION

This open-file report presents a collection of data and information on seismic events felt in Ohio from 1776 to 1998. Included are events known to be earthquakes inside or outside of Ohio, as well as events of human origin. The Annotated Catalog of Earthquakes in Ohio and Adjacent Areas is organized into three sections:

- Earthquakes in Ohio of 2.0 Magnitude or Greater (129 events).
- Border Region Earthquakes (76 events).
- Events of Non-earthquake Origin or Doubtful Earthquakes (24 events).

Each of the sections has additional introductory material regarding reporting methods, event characterization, and the selection process for inclusion in this catalog

### PREVIOUS WORK

This catalog of Ohio earthquakes is based primarily on the chronological catalog of earthquakes east of New Madrid, Missouri, compiled by Seeber and Armbruster (1991), with additions and some deletions. The narratives for Ohio earthquakes have been compiled from a variety of sources, including previous catalogs, governmental agency records, newspaper accounts, and some unpublished accounts compiled by John G. Armbruster of Lamont-Doherty Earth Observatory at Columbia University. Basic data for many earthquakes have been compiled by a variety of government agencies. For the period of about 1872 through 1924, earthquakes were listed in the Monthly Weather Review, published by the U.S. Department of Agriculture. Beginning in 1926, the U.S. Coast and Geodetic Survey began compiling and publishing yearly reports on earthquakes in the United States. In 1961, the U.S. Geological Survey (USGS) published the Preliminary Determination of Epicenters (PDE), with weekly, monthly, and yearly summaries. During the 1970s, the U.S. Environmental Science Services Administration, succeeded by the National Oceanic and Atmospheric Administration, published annual summaries of United States earthquakes. From the early 1980s to the present, the U.S. Geological Survey assumed these duties. Stover and Coffman (1993) provided a complete listing of these publications, including the various authors and administrative affiliations. Docekal (1970) did a very thorough review of earthquakes of the mid-continent region, including Ohio. Many of his sources included references cited herein but also, he used the unpublished notebooks, scrapbooks, and card files compiled by H. F. Reid and archived by the U.S. Coast and Geodetic Survey. Ohio newspapers, county histories, and other documents are in the Archives Library of the Ohio History Connection in Columbus.

Locally, the John Carroll University Seismological Observatory issued annual reports from 1947 until 1991. Primarily, these bulletins provided data on teleseismic earthquakes, but they do include information on local and regional events. In late 1986, the John Carroll observatory installed a multistation network in northeastern Ohio and, from 1987 to 1991 (the observatory closed in mid-1992) dual reports were issued: (1) the traditional listing of teleseismic earthquakes and (2) the John Carroll University Seismic Network Bulletin, which provided data on local seismic activity.

Beginning in 1977, the Anna Seismic Network was operated in western Ohio and eastern Indiana by the University of Michigan. This network closed in mid-1992. The U.S. Nuclear Regulatory Commission issued a

series of reports from this network. Ruff and others (1994) published the final report in this series, which contains a summary of the events recorded by the Anna Seismic Network during its existence.

Bradley and Bennett (1965) provided the first comprehensive catalog of Ohio earthquakes, which included much original research on events, compiled mostly from newspaper accounts. Their concentration seems to have been more on original accounts of western Ohio earthquakes rather than elsewhere in the state. Von Hake (1976) published a brief summary of Ohio earthquakes.

Weston Geophysical Corporation (1979) did a very detailed search of newspaper accounts and records in governmental agencies on earthquakes in northeastern Ohio as part of a contract with the Nuclear Regulatory Commission for assessing environmental impact of the Perry Nuclear Power Plant. This research better defined the locations and intensities of many earthquakes and eliminated some nonseismic events listed in previous compilations as earthquakes.

For some events, the data are abundant and probably comprehensive; indeed, extensive felt reports may be briefly summarized in this report. However, for many events, especially small-magnitude, preinstrumental earthquakes, only very basic information has been compiled. In most cases, new information would consist of newspaper accounts throughout the area in which an earthquake was felt. Gathering such information for each event is time intensive, necessitating long hours at archival institutions. Unfortunately, there has not been adequate time in the course of the current study for such comprehensive analysis for each earthquake. This shortcoming is readily apparent by the brief entries for many events. Seeber and Armbruster (1993) have demonstrated the value of comprehensive evaluations of newspaper reports for some earthquakes. These authors have been able to relocate epicenters by tens of kilometers and adjust felt-area magnitudes by a whole number, or more. In a few cases, they have been able to remove earthquakes from the catalog after investigation demonstrated that they were nonseismic events.

The catalog consists of three parts: (1) annotated listing of earthquakes, or presumed earthquakes, of 2.0 magnitude or greater within the borders of the State of Ohio; (2) earthquakes, or presumed earthquakes, in Ohio's border regions that were, or may have been, felt in Ohio; (3) nonseismic events and uncertain or doubtful earthquakes in Ohio—this category may include some events that were earthquakes but for which available information is equivocal or inconclusive. Some events that are listed in the catalog of known or probable earthquakes have a degree of uncertainty about them (indicated) and could conservatively be placed in the listing of uncertain or doubtful events. A subjective judgment was made on the basis of the original accounts to include these events in the known or probable portion of the catalog.

The events included herein are described using epicenter location (lat, long), intensity, and magnitude. Intensity is a numerical representation of the effects on people, infrastructure, and Earth's surface as a direct result of the event. The event intensities listed in this report refer to the effects outlined in the Modified Mercalli intensity (MMI) scale of 1931 (Wood and Neumann, 1931). Magnitude (M) is a measure of the energy released in the form of seismic waves at the focus of the event. Earthquake magnitude can be determined using several different parameters, including focal depth, distance between the earthquake and recording station, frequency distribution, earthquake duration, and amplitude (table 1).

It must be emphasized that this catalog is a work in progress and will be revised as new information emerges for particular events. The information presented within this report may not be comprehensive for a particular event and does not preclude the necessity of additional research if critical decisions are to be made regarding local seismicity. A narrative is provided for each event so that interested persons can evaluate the quality and comprehensiveness of data used to assign epicentral locations, magnitudes, and intensities to particular earthquakes. It is our objective to contribute to the understanding of seismic risk and seismic hazard in Ohio by providing both available data and pointing out the shortcomings of the data set for future research. The Division of Geological Survey/Ohio Seismic Network welcomes contributions of new data for revisions to the catalog.

Abbreviations and definitions of parameters in the annotated catalog and chronological listing are given in the list of Abbreviations Used in this Report (p. ii). Dates and times in these documents are in Universal Coordinated Time (UTC) unless otherwise noted in the annotations as local time; UTC is 5 hours ahead of Eastern Standard Time (EST) and 4 hours ahead of Eastern Daylight Time (EDT).

**TABLE 1. Comparison chart of seismic magnitude and intensity scales**

Magnitude Scale	Mercalli Scale	Description
0–2.9	I	Detected only by sensitive instruments
	II	Felt only by a few persons at rest, especially on upper floors of buildings; delicately suspended objects may swing
	III	Felt noticeably indoors, especially on upper floors of buildings, but not always recognized as earthquake; standing autos may rock slightly; vibrations like a passing truck
2.9–4.1	IV	During the day, felt indoors by many, outdoors by few; at night, some awakened; dishes, windows, doors disturbed; walls make creaking sound; sensation like heavy truck hitting building; standing autos rock noticeably
	V	Felt by most people; some breakage of dishes, windows, and plaster; unstable objects overturned; disturbance of trees, poles, and other tall objects
4.1–5.4	VI	Felt by all, many frightened and run outdoors; some heavy furniture may move; falling plaster and chimneys, damage slight
	VII	Everyone runs outdoors; damage to buildings varies depending on quality of construction; noticed by people driving autos
5.4–7.3	VIII	Panel walls thrown out of frames; walls, monuments, chimneys fall; sand and mud ejected; drivers of autos disturbed
	IX	Buildings shifted off foundations, frame structures thrown out of plumb; ground cracked; underground pipes broken
	X	Most masonry and frame structures destroyed; ground badly cracked, rails bent, landslides; sand and mud shift; water splashes over river banks
7.3+	XI	Few structures remain standing; bridges destroyed; broad fissures in ground, pipes broken, landslides, rails bent
	XII	Damage total; waves seen on ground surface, lines of sight and level distorted, objects thrown up into the air

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# ANNOTATED CATALOG OF EARTHQUAKES IN OHIO AND ADJACENT AREAS

## Earthquakes in Ohio of 2.0 Magnitude or Greater

### *Events listing*

Summer, 1776  
Coshocton County  
lat 40.2°, long -81.9°  
MMI = VI  
M = 4.0

The earliest Ohio earthquake, for which a written account exists, was noted by John Heckewelder, a Moravian missionary to Native Americans in Ohio. Heckewelder provided his account to Daniel Drake, a Cincinnati physician, who paraphrased the text of Heckewelder's letter, and provided detailed accounts of the New Madrid earthquake series in 1811 and 1812.

Drake (1815) stated:

*The first was in the year 1776. Mr. John Heckewelder, then a missionary of the United Brethren, on the Muskingum River, in this State, has politely favored me with a memorandum concerning it. He does not recollect the month, but it was in the summer, and about 8 o'clock a.m. Its duration was two or three minutes. The southwest side of the house was raised with such violence that the furniture of the room was nearly overturned. It was accompanied with a subterranean rumbling noise. Early in the morning the weather was fair, but previous to the shock it began to thicken in the southwest. The cattle were frightened by the shake, and the Indians continued, after it, to apprehend some great disaster, of which they conceived this to be the precursor.*

From this single account it is impossible to reliably place the epicenter of this event or to accurately determine the magnitude. It is probable that the epicenter was not to the east or to the northeast in Canada, as these areas had some settlement and an account of a strong earthquake in 1776 would have been noted. The epicenter could have been in western Ohio (Anna zone), northern Kentucky, or perhaps as nearby as the

Perry County, Ohio, area. Armbruster and Seeber (1992) assigned a magnitude of 4.0 to this event, based on Heckewelder's description.

Heckewelder's location on the Muskingum River is not specified in his account; however, most of the missionary activity during this period was on the upper Muskingum River (see entry for February 13, 1779). The coordinates for this event have been changed slightly in this report to the general location where Heckewelder might have been residing at that time. Various authors, including Shaler (1869) and Moneymaker (1954) have repeated Drake's account.

February 13, 1779  
Ohio?  
MMI = VI  
M = 4.5

An earthquake that has been only briefly mentioned in previous catalogs was recorded by David Zeisberger, a Moravian missionary, in the diary he kept while at Lichtenau, a village on the Muskingum River in southern Coshocton County, south of Goschochgung (now Coshocton). Zeisberger's diary is in the Moravian Archives in Bethlehem, Pennsylvania. A translation of Zeisberger's account in German script was kindly provided by Vernon H. Nelson, Archivist, of the Moravian Archives:

*On the 13th before noon an earthquake was felt here and in all places at the same time when 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.*

It is evident that this earthquake was felt across the state of Ohio, based on Zeisberger's notation that it was felt by various tribes. The Mingos were in eastern Ohio, in the vicinity of the Ohio River in Jefferson County and surrounding areas. The Wyandots occupied northwestern Ohio. And the Shawnees were along the Scioto Valley and vicinity in the central part of the state, and west to the vicinity of Xenia and Wapakoneta (Noble and Korsok, 1975). Previous catalogs seem to repeat the observation that it was felt in northern Kentucky but make no mention of the wider area noted by Zeisberger. Modern-day earthquakes that have been felt statewide are generally in the 5.0-magnitude range. As with the 1776 event, it is probable that the epicenter of the 1779 event was not to the east or to the north, in Canada, because of lack of accounts in these settled areas. The

epicenter could have been in the Anna zone in western Ohio; in northern Kentucky; or as far west, perhaps, as New Madrid.

May 5, 1804  
Clermont County  
lat 39.1°, long -84.2°  
MMI = Felt  
M = n/a

From *Rockey* (1880), p. 25: "The first shock ever experienced in Clermont County was the one of May 5, 1804."

This is the only mention discovered so far of this probable earthquake. It is assigned to the Ohio catalog because it was felt in Ohio, but it could have had an epicenter in Kentucky or other border area. The earthquake near Chicago, Illinois, on August 24, 1804 (Drake, 1815), which was felt as far west as Fort Wayne, Indiana, does not seem to be the same event noted by Battey, unless the dates were greatly confused. Early events, such as this one, are unlikely to have been caused by cultural sources such as explosions or mining activities. However, published information at such an early date is so sparse that it is unlikely this event will ever be documented fully.

July 8, 1836  
Cuyahoga County  
lat 41.5°, long -81.7°  
MMI = IV  
M = 3.1

Weston Geophysical Corporation (1979) gathered the following accounts of this earthquake. It indicated that the event was not reported in the Painesville and Ashtabula newspapers and had an MMI of III in Elyria. These data suggest that the epicenter was in the Cleveland area.

From *Cleveland Advertiser*, July 14, 1836:

*Earthquake—Between the hours of 9 and 10 o'clock last evening a shock of an earthquake was experienced in this place and its vicinity which although of momentary duration was of such force and extent as to leave no doubt of its nature. The effect of it in the room where we were sitting was to jar the windows and furniture as if a heavy body had fallen in the room above. The shock was accompanied and succeeded by a dull rumbling sound.*

From *Elyria Republican and Working Mens Advocate*, July 13, 1836:

*Earthquake.—About 15 minutes past 9 o'clock on Friday evening last, our citizens felt a smart shock of an earthquake accompanied with a distant rumbling noise. The motion of the earth was quite perceptible.*

From *Cleveland Herald*, July 9, 1836:

*A slight shock of an earthquake was experienced in this city last evening between the hours of 9 and 10.*

June 19, 1843  
Champaign County  
lat 40.1°, long -83.8°  
MMI = IV  
M = 3.5

John G. Armbruster has provided the following newspaper account of this event. From *Ohio State Journal*, July 12, 1843:

*Quote from the Urbana Citizen—"About six o'clock on the evening of the 19th ult. [ultimo = preceding month], a rumbling noise and jarring of the earth, similar to that produced by the shock of an earthquake, was very sensibly heard and felt in various parts of this county."*

Urbana is in Champaign County. It is possible that this earthquake was in neighboring Shelby County, perhaps near Anna. This area was sparsely settled in 1843. The town of Anna was platted in 1858 and incorporated in 1877.

April 6, 1848  
Hocking County  
lat 39.65°, long -82.53°  
MMI = IV  
M = 3.7

Ann Metzger's (CERI) research on this event suggests that the epicenter was southeast of Lancaster because this was the only town to feel three shocks, and indications from Circleville are that the shock was felt more strongly to the southeast. A 3.7 magnitude earthquake on April 8, 1967, was assigned to this location. John G. Armbruster has supplied the following newspaper accounts of this earthquake.

From *Zanesville Gazette*, Wednesday, April 12, 1848:

About 8 o'clock on last Thursday evening many of our citizens observed what appears to be two distinct shocks of an earthquake. The same report is brought from the country and *The Licking Herald* alludes to it having been distinctly noticed there. We have not yet seen a notice of it in any other quarter.

From *Licking Herald* (Newark), April 19, 1848:

We alluded last week to the first of two shocks of an earthquake having been felt here about 8 o'clock on the evening of the 6th. We have seen notice of it having been felt at Marietta, Chillicothe, Newark and the immediate country but do not learn that it was felt more sensibly any where else than here. Some one here stated the report that half of New Orleans had been sunk by it, and the rumor seems to have run through the county like wild fire. It is scarcely necessary to say that the story is without foundation.

October 1, 1850  
Cuyahoga County  
lat 41.42°, long -81.55°  
MMI = IV  
M = 3.2

Weston Geophysical Corporation (1979) collected the following newspaper accounts of this earthquake. Seeber and Armbruster (1993) relocated this event based on newspaper accounts.

From *Cleveland Daily Herald*, October 1, 1850:

A very sensible shock of an earthquake was felt at this place this morning (Oct. 1) at about 5:25 o'clock. The first indication of the phenomenon was a low rumbling sound somewhat like distant thunder apparently in a northwesterly direction. This sound increased in intensity for about 3 or 4 seconds, the deepest intonations being like very heavy distant thunder, the earth at the same instant exhibited a trembling motion which lasted nearly two seconds when it gradually died away with the sound in an easterly or southeasterly direction. The concussion was so violent that it produced a jarring and rattling of the windows, furniture

and crockery and a very sensible trembling could be felt by one who stood up on the ground. In Euclid about 8 miles east of this city the shock was sufficiently violent to throw crockery from the shelf. We also learn by a gentleman from Berea (about 12 miles southwest) that the concussion were sufficient to awaken persons from their sound sleep.

From *Cleveland Daily True Democrat*, October 2, 1850:

About 5:20 yesterday morning the shock of an earthquake was felt distinctly by our citizens. It was accompanied by a rumbling noise similar to the roar of distant thunder and appeared to vibrate from the west to the east. The houses in the city were jarred for several seconds. It was observed at Parma, Brecksville, Strongsville, Rockport, and Euclid.

January 10, 1854  
Highland County  
lat 39.4°, long -83.7°  
MMI = IV  
M = 3.5

Ann Metzger has provided the information on this poorly known earthquake, which has been assigned the coordinates of Hillsboro, as this is where it was most strongly felt. The *Highland News* (Hillsboro) reported three or four distinct shocks, a rumbling noise, heavy furniture displaced, window-sash and doors slammed and rattled, many ran outdoors, and hanging objects began to swing. The *Wilmington Herald* (Clinton County) and *Wilmington Republican* reported three distinct shocks, windows rattled, and it was felt in several other places in the county. Additional research is needed on this event.

September, 1859  
Clermont County  
lat 39.1°, long -84.2°  
MMI = F  
M = n/a

From Rockey (1880), p. 25—"In 1859 a slight shock was felt in September, and again in 1864; but these were scarcely perceptible."

This event is not listed in previous earthquake catalogs and requires additional research.

1864  
Clermont County  
lat 39.1°, long -84.2°  
MMI = F  
M = NA

From Rockey (1880) "In 1859 a slight shock was felt in September, and again in 1864; but these were scarcely perceptible."

This event is not listed in previous earthquake catalogs and requires additional research.

February 7, 1868  
Cuyahoga County  
lat 41.5°, long -81.6°  
MMI = F  
M = n/a

John G. Armbruster discovered an article in the *Cleveland Leader*, February 11, titled, "Jack Frost, or an Earthquake?" The article stated:

*It is believed by a vast number of people that the city was visited by a small earthquake on Thursday night. About 8 o'clock a shock was felt by residents in different parts of the city, and the phenomenon was repeated an hour later. The sensation was that of a heavy concussion. Other slight demonstrations of a similar nature occurred during the night. The cause was attributed by many at the time to the action of the frost on the house foundations. In the morning large cracks were found in the ground in various localities. Similar shocks were felt at Tiffin and several towns along the Lake.*

This event, or series of events, is enigmatic. The fact that the 8:00 p.m. (EST; 01, February 7 UTC) event was felt by a large number of people throughout the city suggests that it was an earthquake. If the tremor at Tiffin and various lakeshore communities was at about the same time as the Cleveland event, this would ensure that it was indeed an earthquake.

The suggestion in the *Cleveland Leader* article, that the shaking and noise was caused by sudden contraction of buildings or the ground surface, is not totally a fanciful speculation, as cryoseisms or frostquakes have been documented. Mitronovas (1991) indicated that cryoseisms result when water-saturated surface layers of soil contract and rupture when subjected to sudden and intense freezing. This circumstance can lead to brief but

violent local shaking of the ground and buildings, loud explosive sounds, and formation of numerous ground fractures. Cryoseisms usually occur at night when temperature is lowest. It is unlikely that a single cryoseismic event would be felt throughout the city of Cleveland and certainly not as far away as Tiffin and lakeshore towns.

There remains the possibility that the main shock at 8:00 p.m. EST, and perhaps the event an hour later, were earthquakes but that the "slight demonstrations of a similar nature" during the night were cryoseisms, which created the ground cracks noted in the newspaper account. Additional accounts of the events from other locations may resolve these questions. However, the evidence suggests that an event of seismic origin occurred.

January 16, 1870  
Fairfield County  
lat 39.71°, long -82.60°  
MMI = II  
M = 2.9

John G. Armbruster provided the following newspaper account of a possible earthquake felt in Lancaster, Fairfield County. This event requires additional research for confirmation.

From *The Picayune*, New Orleans, Louisiana, January 23, 1870:

*Columbus, Ohio, Jan. 17—A member of the Ohio senate has just arrived here from Lancaster, who reports that at 15 minutes past 4 yesterday afternoon a shock of an earthquake was distinctly felt in that city in the house of Col. Best, and the vibration was very considerably felt, and 17 panes of glass were broken. The shock was also felt in the house of C. F. Garrety. Dishes were rattled and glass broken. It is not thought to be the effect of electricity, as the flash of lightning did not appear at that time, or in connection with the thunder, until some time after.*

January 4, 1873  
Delaware County  
lat 40.2°, long -83.0°  
MMI = IV  
M = 3.8

John G. Armbruster discovered accounts of this earthquake, which was not previously listed in catalogs. The most extensive report was in the *Ohio*

*State Journal*, Columbus, on January 6, 1873. This report indicates that many thought an explosion had occurred: "Very distinctly observed in many different parts of the city." Some reported dishes and stoves rattling and others described it as "a distinct report, with a concussion." It was noted that reports of the shock came from every part of the city of Columbus. Some said the shock came from the northwest while others said it came from the northeast.

Armbruster found a brief comment in the *Delaware Gazette* that the shock "was noted by many persons in Delaware, and at various parts throughout the county." He also found a report in *The Columbus Dispatch*, January 7, that indicated the "earthquake was felt at Newark." Newspapers in Circleville, Lancaster, and Mt. Gilead repeated the report of the earthquake in Columbus but did not indicate that it was felt in their cities. These newspapers reported that it was felt in Dayton; however, Armbruster could not find any accounts of the event in Dayton newspapers, suggesting that the Dayton report was erroneous and simply repeated in various newspapers.

This presumed earthquake is somewhat enigmatic in that it occurred in central Ohio, which is in the center of a several-county area that has not previously reported historic seismicity. The felt reports, from the center of Franklin County (City of Columbus at that time) and apparently a large area of Delaware County to the north, and east to Newark, suggest an epicenter for the event in northern Franklin or southern Delaware Counties.

April 23, 1873  
Montgomery County  
lat 39.7°, long -84.2°  
MMI = IV  
M = 3.0

Docekal (1970) cited Rockwood (1873) as the source of the note: "a slight shock felt at Dayton." This event requires confirmation and further documentation.

June 18, 1875  
Shelby County  
lat 40.2°, long -84.0°  
MMI = VII  
M = 4.7

Stover and Coffman (1993) summarized this significant earthquake in the Anna Seismogenic Zone: "This earthquake was most severe west of

Columbus, at Urbana (Champaign County) and Sidney (Shelby County), where chimneys were thrown down and walls were cracked. Also felt in southern Illinois, southwest Indiana, northwest Kentucky, and eastern Missouri." The following newspaper account describes the event at various locations.

From *The Advertiser-Tribune*, Tiffin, Ohio, June 18, 1875:

*Anna, O., June 18. – A shock of an earthquake passed this place today 9:50 A.M., causing general consternation. Goods were thrown from the shelves, chimneys torn down, and considerable damage done. The loss in one drug store will be at least \$100. There are few places where damage was not done both in town and country. The shock did not last more than half a minute. The clocks were stopped at the moment of the shock. At the hour of writing the corners are crowded with philosophers (?) while some are at home looking for another, and others are writing up the account of a thing heretofore unknown in this region.*

*INDIANAPOLIS, June 18. – A slight shock of an earthquake was felt here this morning at 9:45. Buildings swayed to a considerable extent, and in some instances windows rattled.*

*ANDERSON, IND., June 18. – Very strong; shook buildings all over the town.*

*JEFFERSONVILLE, IND., June 18. – Felt quite sensibly.*

*VINCENNES, IND., June 18. – Felt a jar considerably.*

*SIDNEY, O., June 18 – Houses were shaken badly, causing the people to run out. At Anna, six miles north of here on the Dayton & Michigan Railroad, it cracked all the houses, knocking chimneys down, and goods, etc., off the shelves in stores. No one was reported killed.*

*DEGRAFF, Ohio., June 18. – A terrible shock, resembling an earthquake, jarring buildings almost from their foundations, was felt here.*

*URBANA, O., June 18. – The shock swayed buildings, their motion being perceptible.*

June, 1876  
Shelby County  
lat 40.4°, long -84.2°  
MMI = V  
M = 3.4

Rouse and Priddy (1938) listed this event in the Anna Seismogenic Zone as “intense.” No source for their listing was given.

January 23, 1877  
Adams County  
lat 38.8°, long -83.5°  
MMI = III  
M = 3.4

Bradley and Bennett (1965) referenced articles in the Cincinnati Commercial Tribune and the *Shelby County Democrat*. “Shock primarily felt in Brown and Adams counties in south central Ohio. Accompanied by a rumbling noise. Also felt in northern Kentucky.”

August 30, 1881  
Highland County  
lat 39.2°, long -83.7°  
MMI = III  
M = 2.9

Docekal (1970) reported, “A slight shock was reported at Hillsboro, Ohio, and vicinity.” His sources were Rockwood (1882) and the unpublished notebooks of H. F. Reid.

February 9, 1882  
Shelby County  
lat 40.4°, long -84.2°  
MMI = V  
M = 3.1

Bradley and Bennett (1965) referenced an article in the *Shelby County Democrat*: “Two distinct shocks felt at Swanders and Botkins, near Anna. Windows and dishes rattled. People rushed into streets. Ground reportedly moved toward northeast.”

January 5, 1883  
Lorain County  
lat 41.35°, long -82.1°  
MMI = IV  
M = 3.4

John G. Armbruster has collected the following newspaper reports pertaining to this event. Docekal (1970) referenced the unpublished files of H. F. Reid and Rockwood (1884) on this earthquake but stated only: “An earthquake was felt in northern Ohio. No details.”

From *Cleveland Leader*, January 8, 1883:

About 5:30 o'clock last Friday morning several distinct shocks were experienced by the people residing in the northern part of Lorain and the western part of Cuyahoga counties. The vibrations were of such strength that windows were violently shaken and many people awakened from sound slumber. The first news was brought to the city yesterday by people residing in Elyria, Lorain, and Litchfield, where the shock was most perceptible. I have made inquiries of numerous people residing in various sections of the northern part of Lorain County, and have found that all to whom I have spoken were awakened by the shock, which passed through Lorain, Elyria, and Litchfield, and must have been felt in the western suburbs of Cleveland. It was plainly felt on the Lake Shore about twenty-five miles west of here (Rocky River).

The *Cleveland Herald* stated: “Reports from the west and southwestern country near the city confirm the report of a shock of earthquake being felt, especially in Lorain and Medina, in Medina County.”

September 19, 1884  
Allen County  
lat 40.7°, long -84.1°  
MMI = VI  
M = 4.8

This significant earthquake was in the western Ohio seismogenic zone and was felt throughout most of Ohio and parts of adjacent states. Rockwood (1885) gave accounts of the earthquake and presented a felt-area map. Stover and Coffman (1993) summarized the event and presented an isoseismal map:

*Slight damage occurred at Lima, where the shock was “of considerable violence and caused much excitement.” Plaster was shaken from ceilings east and southeast of Columbus at Zanesville, Ohio, and Parkersburg, W. Va. Windows and dishes were broken at Defiance and Norwalk, Ohio; to the west at Fort Wayne and Muncie, Ind.; to the north at Lansing, Mich.; and to the east at Wheeling, W. Va. Furniture was displaced and*

buildings were heavily shaken at Urbana, Ohio, in Champaign County, and at many other towns in the regions. Also felt in Iowa, Kentucky, Pennsylvania, and western Ontario, Canada, and at Washington, D.C. by workmen on top of the unfinished Washington Monument.

The following are contemporary newspaper accounts of the earthquake.

From *Crestline Advocate* Crestline, Ohio, September 26, 1884:

A genuine earthquake visited this locality last Friday afternoon at 2:45, in which houses were made to tremble and furniture rattle. Several persons ran from dwellings and business houses, expecting everything to "fall in." The swaying motion was very distinct, running east and west. The sensation was something new in this section. The experience here was the same as that telegraphed from numerous portions of the State. Our neighboring towns, also, reported a lively shaking up. James Booth says that, at the time of the occurrence, he was thrown from a lounge on which he was lying, then bounded up from the floor, whirled around, and went scooting out of his front door up into the air, and when he collected his scattered senses he found himself on the roof of his domicile, standing on his head. He didn't say this in just so many words, but this was inferred from the experience he related.

The *Crestline Advocate* listed accounts from various communities, of which excerpts are presented here.

CLEVELAND, Ohio., September 20. – Yesterday afternoon an earthquake was felt in many parts of this city. Tables and furniture were moved in the houses, pictures on the walls were shaken, causing quite an excitement among the inmates. The motion was from west to east and was confined to three distinct rockings finally subsiding and dying away in a sort of a tremor.

CINCINNATI, O., September 20. – At 2:30 yesterday afternoon the shock of an earthquake was felt in this city and in Covington, Ky. There was a slight trembling of buildings and rocking motion felt, which was sufficiently marked to cause astonishment and comment. The motion was from north to south

and was a gentle undulation, without any tremor or upheaval. The shocks lasted about ten seconds, there being a perceptible pause between the first and second. A gentleman, who was writing at home on Cutter Street, said he felt his table vibrate. It stopped and then moved again less violently than before. Reports from Mt. Vernon and Delaware, Ohio, say the shock was felt at their places.

COLUMBUS, O., September 20. – At 2:40 p.m. yesterday, a shock of earthquake was felt in different parts of this city, the vibrations lasting over thirty seconds. At the Capitol (sic) University the chandeliers swayed to and fro and students left their rooms amid great excitement.

AUBURN, IND., September 20. – There was quite a heavy shock of an earthquake felt here at 2:15 p.m. yesterday, lasting about ten seconds. Brick blocks were perceptibly rocked from east to west, and much excitement naturally prevailed. No damage was sustained. The shock was felt along the line of the postal telegraph from Ligonier, Indiana to Wellington, Ohio.

LANSING, MICH., September 20. – About three o'clock yesterday afternoon this city, and vicinity, was perceptibly shaken by an earthquake, causing the large Capitol building to tremble. No serious damage has been heard of.

DETROIT, MICH., September 20. – A horizontal motion was felt throughout the city at 2:42 yesterday afternoon. From the tallest blocks came telephone messages to the NEWS office asking what it was.

ADRIAN, MICH., September 20. – A slight shock of an earthquake was felt here yesterday afternoon.

ANN ARBOR, MICH., September 20. – About 2:40 yesterday afternoon, quite a sensible shock of earthquake was felt in this city.

PORT HURON, MICH., September 20. – An earthquake shock was felt here at 2:45 yesterday afternoon.

YPSILANTI, MICH., September 20. – A severe shock of earthquake was felt here at

2:45. People rushed into the streets  
frightened badly.

CECIL, O., September 20. – A violent  
shock of earthquake rocked this town at  
2:17, throwing goods from the shelvings. In  
the depot the passengers rushed out,  
thinking a train had struck the building. It  
lasted ten seconds.

ARCHIBALD, O., September 20. – At 2:13  
p.m., standard time, an earthquake lasting  
about twenty seconds passed through town.  
The buildings shook. No serious damage  
done.

FOSTORIA, O., September 20. – At 2:19 an  
earthquake shook the town slightly.

DEFIANCE, O., September 20. – At a few  
minutes before 3:00 o'clock a very  
perceptible earthquake was felt at this place  
and throughout surrounding country.

TOLEDO, O., September 20. – A slight  
shock of earthquake was felt in the suburbs.  
The pictures and furniture in one house  
began to move around in a crazy manner.

AKRON, O., September 20. – Two distinct  
shocks, resembling that of an earthquake,  
were felt at this place at 2:40 yesterday  
afternoon.

December 23, 1884  
Shelby County  
lat 40.4°, long -84.2°  
MMI = III  
M = 2.9

Bradley and Bennett (1965), summarizing a  
report in the *Shelby County Democrat*, reported:  
“Distinct shock felt at Anna. Ground seemed to  
move from northwest to southeast. Duration of  
shock several seconds.”

January 18, 1885  
Summit County  
lat 41.15°, long -81.55°  
MMI = IV  
M = 3.8

The following newspaper accounts were  
collected by Weston Geophysical Corporation  
(1979). Seeber and Armbruster (1993) relocated  
the event.

From *Cleveland Herald*, January 22, 1885:

Akron, Ohio, Jan. 21 – (Special) – Reports  
come from the northern townships of the  
county of a pronounced earthquake shock  
felt there early Sunday morning. A number of  
Akronians who felt it, but would not speak of it  
for fear of ridicule, are now coming to the  
front.

From *Cleveland Herald*, January 23, 1885:

Plymouth, Jan. 22 – ...Since your  
correspondent at Akron opened up the  
subject we can add a little about that  
earthquake on late Sunday morning. It was  
felt here by several persons. In one house the  
dishes fell from cupboards and in some  
places a loud report as of an exploding gun  
was heard. The subject was not mentioned  
at first by the parties noticing it for fear of  
ridicule, thinking possibly they were mistaken.

From *Monthly Weather Review*, Jan., 1885,  
United States Weather Bureau, Washington, D.C.:

Mr. S. M. Luther of Garrettsville, Portage  
County, Ohio, reports that during the early  
morning of the 18th a shock, supposed to  
have been due to an earthquake, occurred at  
that place. He also states that several persons  
in the vicinity of Garrettsville noticed the shock.  
The time at which it occurred was about 5:30  
or 5:45 a.m.

From *Painesville Telegraph*, January 22, 1885:

Last Sunday morning between 4 and 5  
o'clock several shocks, or explosions were  
heard and felt as though some heavy body  
had been thrown against the house; the last  
one a little before 5 o'clock was so violent as  
not only to jar the houses, but the furniture  
and to disturb those in bed. Even hanging  
lamps rattled and vibrated. The what is was  
has not been settled, some thinking it the  
action of the frost and others that a real  
earthquake was traveling about.

From *Summit County Beacon*, Akron, Ohio,  
January 28, 1885:

A shock as of an earthquake was  
distinctly heard and felt on Sunday morning  
at 5 a.m., by a great many people, your  
correspondent included. So says a Twinsburg  
letter. Kent had the 'earthquake', too. At  
least the *Bulletin* says: Last Sunday morning a

heavy shock and sound resembling that of an earthquake was heard through this section of, Portage County. Many persons were aroused from their beds by the noise, which in some instances resembled the sound of some heavy body falling upon the roof of the house. The shock was distinctly heard in Brimfield.

From *Summit County Beacon*, Akron, Ohio, February 4, 1885:

Orville Crescent: Persons at Wooster, Akron, and other parts of Summit County, report that they felt the shock of an earthquake on Sunday of last week. We understand that the shock was felt quite distinctly at Burton City.

May 3, 1886  
Athens County  
lat 39.36°, long -82.24°  
MMI = V  
M = 3.8

Docekal (1970), citing the unpublished notebooks of H. F. Reid and an account in the *Monthly Weather Review* (1886), said: "A slight shock lasting 1 second was felt in a circular area with a 70 mile diameter around Trimble, Ohio. Within the area lie Chillicothe, Circleville, Lancaster, New Lexington, Pomeroy, Wellston, Ohio; and Parkersburg, West Virginia." The following newspaper account adds more detail and suggests that the earthquake was more than a slight shock and lasted more than one second.

From *Athens Messenger*, May 6, 1886:

About half-past nine o'clock Sunday night the serene quietude of our peaceful community was abruptly broken by deep and alarming subterranean rumblings which at once brought to the startled apprehension of local dwellers that they were realizing the novel experience of an earthquake. The shock lasted from six to eight seconds and was vigorous enough to give every house in town a lively shaking up and in many of which the vibrations were violent enough to visibly move beds and other heavy pieces of furniture and in very many instances to displace or overturn mantle ornaments, noisily rattle the dishes on tables and shelves, open and close doors, set rockers in motion and to produce many other queer performances. A sequence of this underground agitation worth naming is

that the water, very generally, to the wells here was found to be muddy next morning, evidently the result of the commotion to which it had been subjected.

A like commotion was observed during the rumpus to agitate the waters of the asylum Lakes and during which, our informant tells us, a multitude of fish were seen to wildly leap above the surface. At the asylum, the effects of the 'quake' (for short) were materialized in the various ways experienced in town and many of the patients in the several wards were wrought to a high tension of excitement.

The effect of the shock was felt throughout the county, citizens from various parts of which relate experiences similar to those above narrated. According to our information at the time of writing this, the territorial range of the shock was circumscribed by limits of perhaps 80 miles from east to west, beginning somewhere in the region of Parkersburg, and from south to north, in very nearly the course the energy of the shock was seemingly exerted. The extent of the country affected approximates a hundred miles, with Athens as the central point.

September 11, 1886  
Wayne County  
lat 40.97°, long -81.70°  
MMI = IV  
M = 3.1

John G. Armbruster provided the newspaper articles pertaining to this event. This appears to be an earthquake of seismic origin. The reference to the shock being felt in a coal-mining region, and land subsidence some years prior to this event, is not conclusive evidence that this shock was due to mine subsidence. Doylestown (northeastern Wayne County), noted in the second article, had active coal mines at the time of the event (Conrey, 1921). However, it is unlikely that collapse of a portion of the roof in an underground coal mine would have been felt throughout more than a very local area and would not have sufficient force to throw objects from the mantel except directly above the subsiding mine roof. The report that it was felt throughout a wide area is strong evidence that this was not mine subsidence or a methane explosion. One newspaper report indicates the event was on Saturday morning; the other indicates Sunday morning. The date of September 11 (Saturday) is taken as the correct one as it is from an original report from Akron, whereas the

other report is copied from a story in a Chicago newspaper.

The association with the meteor passage is coincidental. The fireball was obviously luminescent during its passage over the shaken area and was seen as far east as Pittsburgh. It is unlikely that sonic booms would have accompanied its passage during this portion of the atmospheric entry and certainly impossible that it hit the ground near Doylestown and skipped back into the atmosphere.

From *Columbus Dispatch*, September 13, 1886:

*The people living in the coal mining regions, embracing four towns and quite a large range of country, were awakened at four o'clock, Sunday morning by low, rumbling sounds, accompanied by shocks of earthquake so distinct, that houses were terribly shaken and articles on mantels were thrown to the floor.*

*Several years ago the earth settled several feet without apparent cause in this region, and the people are now badly frightened, fearing they will be swallowed up. To make matters more unpleasant a very large meteor, yesterday morning, passed over the shaken up portion of the country, traveling close to the earth and throwing off heated particles every few feet.*

*The meteor illuminated the country for a great distance, and is supposed to have struck the earth near the eastern part of the city, as the shock in that locality was distinctly felt immediately after the great fire-ball passed. The Sunday was one of special prayer by many people.*

From *Akron Beacon*, September 13, 1886:

*Was it the Meteor or an Earthquake? People residing in and about Doylestown are undecided as to whether the disturbance felt in that section of country on Saturday morning was an earthquake or whether it was caused by the great meteor which passed over that place at that time; was seen even in this city and stirred up Pittsburg and other places east of here. Mr. Lyman Frank, residing west of Doylestown, says the shock was so distinct at his house that the tables in his house flapped their wings much to the discomfiture (sic) of his family. The theory now advanced is that the meteor struck the earth in that vicinity causing*

*the jar and then bounding into the air again rushed on in its easterly course. From all points from which reports of the meteor come the story is told of the great fire ball throwing off small portions with grand effect to the view. The appearance of the meteor about the same time the shock was felt has created no little alarm on the part of nervous people many of whom are inclined to the belief that the Charleston woman's prediction of the 'end of the world: for Sept. 29, will be realized.*

February 11, 1888

Summit County

lat 41.0°, long -81.5°

MMI = V

M = 3.4

John G. Armbruster found the following newspaper account. There is some question that this event was an earthquake and it is possible that local mine subsidence caused the disturbance. However, Douglas L. Crowell, ODNR Division of Geological Survey coal geologist, checked state mining reports for this date and could not find any indications of mine subsidence or methane explosions in this area. Sandy Hill could not be located on current maps. The coordinates assigned to this event are generalized. There were two shocks; one at 02:00 UTC and one at 07:30 UTC.

From *Akron Beacon*, February 15, 1888:

*The rural residents of Sandy Hill, Coventry Township, located about four miles south of Akron, were on Thursday night and Friday morning thrown into a state of consternation by a subterranean explosion which swayed buildings and greatly frightened the good people of that quiet section. A reporter visited residents of the area and collected the following accounts. Mrs. Snyder, badly frightened, said "I thought it was an earthquake. The shock almost threw me out of bed. I woke up my husband and had him make a fire and we did not sleep any more that night. The first shock occurred about 9 o'clock in the evening, and the second between 2 and 3 o'clock Friday morning. Mrs. Snyder showed the reported fissures or crevices that crossed the road, that were partially filled, and supposedly caused by the event.*

*At the home of Lester Allen, they said that they heard the explosion and were greatly frightened. Squire James Porter said, "the*

family heard the report but were not so badly shaken up. In the Winter of '82 or '83, an explosion occurred which came near leveling the Porter residence to the ground. The walls and ceilings still show the cracks made by the violent convulsion at that time, but the Thursday and Friday explosion was in another direction, hence the Porter family were not so badly frightened as their neighbors." A. A. Schwartz said, "It sounded like a cannon. I thought it would shake the building down. It is a strange thing and I can't account for it." When queried if something like this had happened before, Schwartz replied, "Oh yes. Several times. I remember when I was a boy of being awakened in the night by a report like a cannon: followed by a low, rumbling sound. That was about 25 years ago."

The reporter noted that Prof. Edward Claypole of Buchtel College and Prof. M. C. Read of Hudson, "made an examination of the fissures made by a previous explosion." Prof. Claypole thought the disturbance was caused by the escape of gas from underground, which had escaped beneath the superficial layers of gravel and sand. It is probably what is known as *shale gas*. Prof. Read substantiates the gas theory. Others ascribe the phenomena to a subsidence caused by the excavations in adjacent coal mines. Many people in the city also say they heard the explosion.' Claypole (1888) published a short article on the event.

September, 1889  
Shelby County  
lat 40.4°, long -84.2°  
MMI = III  
M = 2.9

Rouse and Priddy (1938) listed a "slight" earthquake for the Anna area but gave no source for their information. Bradley and Bennett (1965), citing Rouse and Priddy, reported, "slight earthquake near Anna."

April 15, 1892  
Mercer County  
lat 40.55°, long -84.57°  
MMI = IV  
M = 3.8

John G. Armbruster discovered the following accounts of an earthquake in the Anna Seismogenic Zone.

From *Mercer County Observer*, April 21, 1892:

Last Friday morning about 5:25 a.m. a terrible shock was felt in this vicinity shaking the buildings and rattling the windows as if there had been an explosion, but none have as yet been reported.

From *Mercer County Standard*, April 21, 1892:

Our people were startled on Friday morning last, about six o'clock, by a heavy shock as though a gigantic explosion of some sort had taken place in the vicinity of the town. It was expected that reports of a nitroglycerine explosion in the oil territory would soon reach Celina, but the origin of the mysterious shock has remained a mystery. Houses were jarred and sleepers aroused by it but that is all that is known.

March 15, 1896  
Shelby County  
lat 40.3°, long -84.2°  
MMI = IV  
M = 3.1

Bradley and Bennett (1965) summarized a report in the *Shelby County Democrat*:

Shock awakened some from sleep. Accompanied by rumbling noise. Reported strongest at Sidney. Motion lasted about 1 minute and seemed to travel from northwest to southeast.

October 29, 1898  
Cuyahoga County  
lat 41.49°, long -81.69°  
MMI = II  
M = 2.9

Weston Geophysical Corporation (1979) collected the following newspaper reports.

From *Berea Advertiser*, Berea, Ohio, November 4, 1898: "Three slight but distinct earthquake shocks were felt in Cleveland, Ohio."

From *Monthly Weather Review*, October, 1898, United States Weather Bureau, Washington, D.C.:

Friday, October 23 (misprint for October 29), at Cleveland, Ohio, three successive shocks are reported by the newspapers to have been felt during the night. Prof. E. W. Morley, of Adelbert College, Cleveland, reports several disturbances shown by the

seismograph during October, caused by blasting at a point about 800 feet southwest of the instrument. Only the most powerful blasts made any record. The most vigorous movement occurred on October 29, and was probably due to some seismic disturbance. Prof. Morley further reports that the seismograph was not disturbed during November and December.

From *Youngstown Vindicator*, Youngstown, Ohio, October 29, 1898:

Cleveland, Oct. 29 – Three distinct earthquake shocks were felt in this city early today, each being about 10 seconds in length. The quake was not severe enough to be noticed generally except in tall buildings and on seismographs. The trend of the quakes were (*sic*) to the northerly and southerly direction.

John G. Armbruster provided the following account from *Akron Beacon*, October 29, 1898:

Press reports say that three distinct earthquake shocks were felt in Cleveland Saturday morning. Nothing of the kind appears to have been noticed in Akron.

September 14, 1899  
Lorain County  
lat 41.17°, long -82.12°  
MMI = III  
M = 3.3

John G. Armbruster discovered the following account that was repeated in both the *Cleveland Leader*, September 15, 1899, and the *Cleveland Plain Dealer*, September 15, 1899:

Penfield Township was visited by an earthquake early this morning. First there was a shock lasting about four seconds, which shook dishes, tables, chairs, etc. After the shock there was a rumbling noise lasting fully half a minute.

November 12, 1899  
Ross County  
lat 39.3°, long -83.0°  
MMI = IV  
M = 3.1

Docekal (1970), referencing an article in the *Columbus Evening Dispatch*, reported: "An earthquake, accompanied by rumbling, rattled

windows at Chillicothe, Ohio." This event, however, needs further confirmation.

May 17, 1901  
Scioto County  
lat 38.73°, long -82.99°  
MMI = VI  
M = 4.3

Stover and Coffman (1993) summarized this event.

The strongest effects of this earthquake were reported in Scioto County, near the Kentucky—Ohio—West Virginia border. At Portsmouth, tops of chimneys toppled, bricks tumbled from many chimneys, and windows in several houses were shattered. East of Portsmouth, at Sciotoville, many chimneys were damaged and dishes were thrown from cupboards. At Gallipolis, Gallia County, plaster in one house was shaken loose. Reported felt mainly in the area along the border of Kentucky, Ohio, and West Virginia, including Greenup and Lewis Counties, Ky., and Cabell and Kanawha Counties, W. Va., to the south; Adams and Brown Counties, Ohio, to the west; Muskingum and Washington Counties, Ohio, and, Wood County, W. Va., to the northeast; and Highland County, Ohio, to the northwest.

An extensive report on this earthquake appeared in the Portsmouth, Ohio, *Valley Sentinel*, May 22, 1901; excerpts from that article are presented in the following paragraphs.

Earthquake. That was the common mode of salutation on the street, Thursday. It was the real thing and it was felt by almost everyone in the city and vicinity. The shock came about one o'clock. It was the most severe ever felt in this section. Houses shook like leaves, windows and dishes rattled, bricks began tumbling off chimneys, and everybody but the soundest sleepers were awakened by their beds being shaken violently.

A large number of chimneys about town were damaged by the earthquake. In many instances the tops tumbled down while in others only a few bricks fell down on the roof, causing great fear to the occupants of the houses. Windows in a number of West Front street houses were shattered by the shock. Canned goods were sent tumbling off the

shelves at Reissinger's grocery on East Eleventh.

At Buena Vista the shock was felt very forcibly. Almost the entire village was awakened by a loud report, the rattling of dishes and windows, and the shaking of the houses. Many of the citizens were badly frightened.

This one was the fourth earthquake shock felt in Portsmouth in the past fifteen years, and it was the worst of all. The other three were slight compared with the one this morning. The last shock here was about four years ago on Decoration Day afternoon.

In many parts of the city the people rushed into the street in night attire. Others, more calm, opened their windows and compared notes with neighbors on the other side of the street. Nearly every family had one or more members awake as a result of the disturbance.

Country people were thrown into a state of great excitement by the noise and nearly all seen in town today tell how the shock caused a stampede among their stock and cattle.

The shock seemed to lessen as it left, and the rumbling could be plainly heard in the distance. The sound traveled eastward.

At Wheelersburg the shock was as severe as it was here. Several children were thrown out of bed and at the N. & W. passenger station, the battery fell to the floor and the glass jars were smashed into a thousand pieces.

Lucasville reports that the shock was accompanied by a rumbling noise which many people at first thought was thunder. Houses shook like leaves, dishes and windows rattled and rocking chairs were seen to move. No serious damage was done.

New Boston people were badly frightened by the swaying of their homes.

Sciotoville people were awakened by a rumbling noise. Then the earth began to rock violently, windows rattled, many chimneys fell and dishes were thrown from cupboards and broken. Almost a panic prevailed for a few minutes until the people realized that they had had a dinky earthquake.

The earthquake seems to have been confined to a part of the Ohio valley alone; extending from Marietta to Maysville. It was felt at Chillicothe, but not at Circleville, and on the west, Cincinnati escaped.

Ironton, May 17.—Ironton was visited at about one this morning by an earthquake shock passing directly from west to east. There were a succession of violent undulations lasting thirty seconds. Many residents were roused from their sleep and not a few were nauseated by the rocking of the earth.

Huntington, W. Va., May 17.—Severe shock here at about 2 a.m.

Zanesville, May 17.—Slight earthquake at one a.m.

Wellston, May 17.—Severe earthquake shock at 3 a.m. Many persons ran into the street.

Chillicothe, May 17.—Earthquake felt here at one a.m. Lasted for thirty seconds.

Manchester, May 17.—Earthquake lasted for several seconds. Vibrations from north to south.

Docekal (1970) indicated that at Wellston, furniture was displaced; at Ironton, motion was from west to east for 30 seconds, causing many to awaken and some to sicken. He indicated felt reports from Aberdeen, Hamilton, and Zanesville, Ohio; Maysville, Kentucky; and Huntington, West Virginia.

April 20, 1906  
Cuyahoga County  
lat 41.5°, long -81.7°  
MMI = III  
M = 2.9

Weston Geophysical Corporation (1979) compiled the following newspaper reports on this earthquake.

From Cleveland Plain Dealer, April 21, 1906:

A distinct shock believed to have been a slight seismic disturbance was felt in Cleveland shortly after noon, yesterday. The trembling of the earth was very brief, and not at all severe, but it was felt in all parts of the city.

It was particularly noticeable on the west side of the city. Officials of the Austin Powder Co. say that Father Odenbach of St. Ignatius college informed them that his seismograph had without doubt responded to disturbances in this locality.

*It was about 12:30 o'clock in the afternoon that the disturbance was felt. The first supposition was that an explosion had occurred in one of the manufacturing plants. Careful investigation on the part of the police and others failed to reveal anything in the nature of an explosion.*

From *New York Times*, April 21, 1906:

*Cleveland, Ohio, April 20.—A distant shock, believed by many to have been an earthquake, was felt in various parts of Cleveland at 12:30 o'clock this afternoon. A few minutes later the telephone and newspaper offices were besieged with telephone queries as to where the explosion occurred.*

*A report was circulated that there had been an explosion at the Austion (sic) Powder plant in Newburg, but this proved to be unfounded. Careful investigation failed to show that there had been any kind of an explosion in the city.*

March 27, 1925  
Clinton County  
lat 39.8°, long -83.9°  
MMI = V  
M = 3.4

Bradley and Bennett (1965), summarizing reports in the *Cincinnati Enquirer* and *Shelby County Democrat*, reported: "A distinct earthquake was felt over southwestern Ohio. Furniture was moved and dishes rattled but there was no report of damage."

April 4, 1925  
Hamilton County  
lat 39.1°, long -84.5°  
MMI = II  
M = 2.5

Bradley and Bennett (1965) listed this event as "Earthquake near Cincinnati."

October, 1925  
Shelby County  
lat 40.4°, long -84.2°  
MMI = III  
M = 2.9

Bradley and Bennett (1965) noted: "Slight earthquake near Anna."

October 28, 1926  
Lucas County  
lat 41.7°, long -83.6°  
MMI = IV  
M = 3.4

Bradley and Bennett (1965), summarizing an article in the *Toledo Blade*, stated: "Vibration similar to explosion felt in East Toledo and suburbs. Not thought to be a blast. Two shocks were felt at this location."

November 5, 1926  
Meigs County  
lat 39.1°, long -82.1°  
MMI = VII  
M = 3.6

From *Gallipolis Daily Tribune*, Monday, November 8, 1926:

*An earthquake rocked the rockribbed hills of Meigs County, last Friday, according to a lengthy report published in the Pomeroy Daily Tribune. The tremor is claimed to have occurred at 10:53 A.M. Friday but nothing had been said about it until evening, everyone being afraid to speak about it for fear of being laughed at. Canned fruit was declared to have been jarred from its cellar shelves, stoves turned over and buildings in general given a good shaking. But, no one was injured and damage was slight, the report stated.*

Stover and Coffman (1993) summarized the event:

*This earthquake toppled chimneys at Keno and nearby Pomeroy and overturned a heating stove at Chester, west of Keno. Also, one stovepipe was knocked down at Success, and a flue was downed at Bashan. Explosive earth sounds were reported. Felt throughout, Meigs County, Ohio, and at Letart, W. Va.*

February 17, 1927  
Richland County  
lat 40.7°, long -82.5°  
MMI = IV  
M = 3.1

Bradley and Bennett (1965), referencing the *Columbus Evening Dispatch* and Seismological Notes in the *Bulletin of the Seismological Society of America* (Vol. 17, p. 53), stated: "A series of slight tremors was felt between 05h and 06h 30m near Mansfield. Homes swayed and furniture moved. No damage reported." Recent catalogs have a transposition of the time for these events (05:30 and 6:00). These events are poorly located but may have had epicenters similar to earthquakes that were instrumentally located in 1998 and 2001 in southern Huron County.

October 27, 1928  
Shelby County  
lat 40.4°, long -84.1°  
MMI = III  
M = 3.0

Bradley and Bennett (1965), referencing the *Shelby County Democrat*, stated: "Felt over a 100 sq. mi. area. Center at Jackson Center to Anna."

March 8, 1929  
Shelby County  
lat 40.4°, long -84.2°  
MMI = ?  
M = 3.7

Bradley and Bennett, summarizing articles in the *Cincinnati Enquirer*, *Columbus Citizen Journal*, and *Shelby County Democrat*, stated:

*Felt over 5000 sq. mi. Most intense around Sidney and Bellefontaine. Windows and dishes rattled, furniture shifted, and many sleepers were awakened. Rumbling noise accompanied the earthquake. Two distinct tremors were felt.*

Docekal (1970) added that the earthquake was felt at Piqua and Cincinnati.

June 10, 1929  
Cuyahoga County  
lat 41.5°, lat -81.7°  
MMI = III  
M = 2.9

Bradley and Bennett (1965), summarizing the *Cleveland Press*, stated: "Buildings in suburbs in east side of Cleveland shaken. Possibly due to an explosion." This event was not included in the report on northeastern Ohio earthquakes by Weston Geophysical Corporation (1979).

June 26, 1930  
Shelby County  
lat 40.5°, long -84.0°  
MMI = IV  
M = 3.2

Bradley and Bennett (1965), citing the *Cincinnati Enquirer* and *Shelby County Democrat*, stated:

*A rocking and rumbling of the ground was observed. Most pronounced near Bellefontaine and Lima where dishes and windows were rattled. Was accompanied by a noise similar to a blast. Two shocks were felt by many.*

June 27, 1930  
Shelby County  
lat 40.5°, long -84.0°  
MMI = IV  
M = 3.1

Bradley and Bennett (1965), citing the *Cincinnati Enquirer* and the *Shelby County Democrat*, stated: "Very similar to earthquake of day before, perhaps slightly weaker. Buildings were shaken and beds moved, waking many sleepers."

July 11, 1930  
Marion County  
lat 40.6°, long -83.2°  
MMI = I  
M = 3.1

Bradley and Bennett (1965), referring to an article in the *Columbus Citizen Journal*, stated: "Small buildings were shaken. Some movement of furniture and vibration of dishes." This is the only earthquake reported from Marion County. A 1986 instrumentally located event to the north, in neighboring Wyandot County, suggests that the 1930 earthquake may have had a similar epicenter. Detailed searches of local newspaper accounts may provide more information on this event.

September 29, 1930  
Shelby County  
lat 40.3°, long -84.2°  
MMI = III  
M = 2.9

Bradley and Bennett (1965), citing an article in the *Shelby County Democrat*, stated: "A brief

earthquake shock was felt by many people at Sidney and Anna. The tremor lasted only a few seconds and was accompanied by a rumbling sound.”

September 30, 1930  
Shelby County  
lat 40.3°, long -84.3°  
MMI = VII  
M = 3.5

Bradley and Bennett (1965), citing an article in the *Shelby County Democrat*, stated:

*A brief but strong shock was generally felt over a wide area, with strongest intensity at Anna. The earthquake was strong enough to knock down the chimney on the school and cause plaster to crack and fall. The tremor was again accompanied by a rumbling noise.*

March 21, 1931  
Shelby County  
lat 40.4°, long -84.2°  
MMI = III  
M = 3.0

Bradley and Bennett (1965), citing an article in the *Shelby County Democrat*, stated: “A feeble earthquake shock was felt at Sidney and Jackson Center.”

April 1, 1931  
Shelby County  
lat 40.4°, long -84.0°  
MMI = III  
M = 2.9

Bradley and Bennett (1965) summarized an article in the *Shelby County Democrat*. “Buildings at Jackson Center were shaken by shock. A rumbling noise was heard by many. No damage reported.”

September 20, 1931  
Shelby County  
lat 40.43°, long -84.27°  
MMI = VII  
M = 4.7

The following article describes this event. From *The Bellefontaine Weekly Examiner*, September 25, 1931:

*Persons in Bellefontaine reported that dishes, tables, stoves and even beds were shaken, the disturbance being variously*

*described as similar to that expected by the vibration of a heavy truck passing on the street, as that caused by a nearby explosion of some force or by “an airplane striking a corner of the residence.”*

*At Sidney bricks fell from the United Brethern church and chimneys were knocked from many homes... at Anna ...the plastering was knocked loose in one of the two churches at that place and that foundation pillars under the schoolhouse there were jarred so that they were unsafe for occupancy of the building...*

*Rev. S. J. Mittermaier, pastor of the Anna Lutheran church, reported that two large cornice stones were thrown to the ground at that church.*

*A chimney fell at 6 p.m. from the Webb Long barber shop in St. Marys and several homes were damaged slightly in Wapakoneta.*

*The shocks was (sic) felt at Cincinnati, Lima and as far east as Zanesville, reports said. It was also felt at several cities in eastern Indiana and near the Ohio river in Kentucky.*

October 9, 1931  
Shelby County  
lat 40.4°, long -84.2°  
MMI = III  
M = 2.9

An article in the *Shelby County Democrat*, according to Bradley and Bennett (1965), indicated that “a slight earthquake tremor was felt by a large number of the residents of Anna.”

February 23, 1933  
Shelby County  
lat 40.4°, long -84.2°  
MMI = IV  
M = 3.3

Bradley and Bennett (1965) summarized accounts in the *Cincinnati Enquirer* and the *Shelby County Democrat*:

*Shock felt over four counties. Center of disturbance seems to have been near Sidney, where windows rattled and houses shook. A low rumbling noise accompanied the tremor.*

January 31, 1936  
Seneca County  
lat 41.2°, long -83.2°

MMI = IV  
M = 3.1

Bradley and Bennett (1965), citing Neumann (1938), noted: "A heavy rumbling awakened many in the Tiffin area." Docekal (1970) citing these references and U.S. Coast and Geodetic Survey archival records, stated: "Five distinct shocks accompanied by heavy rumbling awakened many persons in the Tiffin, Ohio, area. Doors and windows rattled."

October 8, 1936  
Hamilton County  
lat 39.3°, long -84.4°  
MMI = III  
M = 3.3

Bradley and Bennett (1965), citing articles in the *Cincinnati Enquirer* and the *Cincinnati Times-Star*, stated: "A slight earthquake was experienced by many persons in the downtown areas of Cincinnati and Middletown. Plates and chairs were moved by the vibrations which lasted about five seconds."

December 26, 1936  
Hamilton County  
lat 39.1°, long -84.5°  
MMI = III  
M = 2.9

Bradley and Bennett (1965) summarized an article in the *Cincinnati Post*:

*Houses in the Cincinnati area were shaken by a slight earthquake. The tremor which lasted ten or fifteen seconds vibrated chairs and was accompanied by a rumbling noise. A second shock very similar to the one above was felt by residents in the Cincinnati area.*

March 2, 1937  
Shelby County  
lat 40.49°, long -84.27°  
MMI = VII  
M = 4.9

This earthquake was the first of two significant, damaging events to strike the Anna area of Shelby County within a week. Newspaper coverage of the events was extensive. Stover and Coffman (1993) provided a succinct summary.

*Damage was heaviest to brick chimneys and buildings at Anna and Sidney—many*

*chimneys fell, walls cracked, and plaster fell. Springs and other water wells increased their flow, but output from oil and gas wells decreased.*

*At Anna public school, walls of the building were cracked so severely that it was declared unsafe; two churches sustained minor damage. Chimneys also were damaged at nearby Botkins and Jackson Center and in southern, Auglaize County, at Wapakoneta. Several tombstones were rotated in three cemeteries near Anna. Plaster fell in buildings as far away as Fort Wayne, Ind., and plaster cracked at Indianapolis. Two to five shocks were felt in many places. Also felt in the States of Indiana, Kentucky, Michigan, and West Virginia, and in Ontario, Canada.*

Rouse and Priddy (1938) and Westland and Heinrich (1940) published detailed studies of the March 2 and March 9 events.

March 3, 1937  
Allen County  
lat 40.7°, long -84.0°  
MMI = V  
M = 3.2

Two small earthquakes, about five minutes apart, occurred the day after the main shock on March 2. They can be considered aftershocks but have been assigned coordinates in Allen County.

March 9, 1937  
Shelby County  
lat 40.47°, long -84.28°  
MMI = VIII  
M = 5.4

This was the second and strongest of the "Anna" earthquakes and is the largest, and most damaging, earthquake to strike Ohio in historic times. Newspaper accounts were extensive and Rouse and Priddy (1938) and Westland and Heinrich (1940) published contemporary studies of the March 2 and March 9 events. Stover and Coffman (1993) have summarized this event:

*An earthquake stronger than the shock on Mar. 2 centered near Anna in Shelby County. The three-story schoolhouse at Anna was cracked severely, and the churches that were damaged in the Mar. 2 shock were further damaged. Almost every chimney was*

broken or twisted, and house foundations and walls were cracked. A few chimneys fell at Sidney, about 12 km south of Anna, and plaster was damaged.

Sub surface changes caused by the two earthquakes included renewed activity of springs, conversion of ordinary wells to artesian wells, and an increase in the flow of other water wells; the output of both oil and gas wells was reduced. A spring at Huntsville (Logan County), dry for 8 years, began 'spouting water' after the second shock, and the flow of artesian wells was increased at New Knoxville (about 45 km west of Huntsville). This shock was felt in upper stories of multistory buildings in Chicago and Milwaukee and in Toronto, Canada. Also felt in Kentucky, Michigan, Missouri, Pennsylvania, and West Virginia.

**The Anna Centennial History (Smedley and Fogt, 1978) provided some local accounts of the events of March 2 and March 9, 1937:**

*On March 2, 1937 at 9:45 A.M. the initial earthquake tremor rumbled through the Village of Anna. This was just a beginning to the temporarily changed life style of the area residents for many months.*

*People streamed into the streets, most heading for the school concerned for the safety of their children. The teacher, however, had the situation under control and the 350 badly frightened but uninjured children scrambled through the falling plaster and dust and out the doors.*

*The quake knocked books off shelves and upset desks in the school. Every third chimney in town was destroyed. One lady, doing her laundry, watched her washer slide across the floor as if it were on a boat in a storm.*

*The damage was assessed and repair work and clean-up began immediately. The vibrations of the first quake had just started to die down when the second, more severe quake struck on March 9 at 12:45 A.M. The residents were rudely awakened and rushed outside. Five minutes later another quake rattled the community, but the devastation had already been done. The partially damaged school building became a total loss. The Lutheran and Methodist churches were heavily damaged, and the Town Hall was so badly damaged that the upper story was condemned and has not been used*

*since. All the chimneys fell, including the ones which had been rebuilt the previous week. Not a home in Anna escaped without some damage and every public building was unfit for use. The area merchants were especially hard hit. Glass store fronts shattered and merchandise was thrown into heaps on the floor.*

*The biggest problem was the school. After the first quake, school was quickly set up in the two churches. After the second quake, the churches were too severely damaged to use. The school, only ten years old at the time of the quake, was destroyed beyond repair. People in town came to the rescue and volunteered spare rooms in their homes for classrooms. School was held in these homes from March 15 to May 28, 1937.*

*The next year some surplus C.C.C. government buildings, brought in from Sidney and placed on the current playground, were used while the new school was being built. Those who had never been introduced to outside plumbing learned what it was all about during that year.*

*Construction of a new school was greatly simplified by the clairvoyance of the Anna School Board who had taken out an unusual earthquake insurance policy. A special, before unheard of, \$30,000.00 earthquake insurance policy was drawn up to protect the big white school which had just undergone extensive remodeling. As a result, Anna had the only school building in Ohio covered by earthquake insurance. At the time of the quake, only \$90.00 had been paid on the original policy, and the \$30,000.00 went a long way in helping to build the new \$165,000.00 structure.*

The Western Ohio Seismogenic Zone is a northwest-southeast-oriented rift zone (known as the Anna or Fort Wayne Rift) of late Precambrian age. The village of Anna seems to have borne the brunt of many earthquakes in the area; however, this may be due to amplification of ground motion by 400 feet of unconsolidated sediments that fill the preglacial Teays Valley, which lies beneath Anna and appears to follow the rift zone. Instrumentally located events appear to confirm that hypocenters are not necessarily beneath Anna. Dewey and Gordon (1984) relocated the 1937 Anna events using contemporary seismograms and placed the epicenters in Auglaize County, northwest of Anna.

Dewey and Gordon (1984) also recalculated the magnitudes of the 1937 Anna events as 4.7 and 4.9 for the March 2 and March 9 events, respectively. Stover and Coffman (1993), however, assigned magnitudes of 5.0 and 5.4 to the March 2 and March 9 events, respectively. This latter determination was based on the felt area of the events. Comparison of felt area, maximum Modified Mercalli Intensity, and damage with more recent events—such as the July 31, 1980 earthquake in northern Kentucky (5.1), the January 31, 1986 earthquake in Lake County, Ohio (5.0), and the July 12, 1986 earthquake in Mercer County, Ohio (4.5)—suggests that the higher magnitudes for the 1937 Anna earthquakes are justified.

April 23, 1937  
Allen County  
lat 40.7°, long -84.0°  
MMI = III  
M = 3.1

This earthquake represents continued activity in the Western Ohio Seismogenic Zone following the main shocks of March 2 and March 9, 1937. Bradley and Bennett (1965), citing articles in the *Shelby County Democrat* and the *Sidney Daily News*, stated: "Slight earth tremor felt at Anna, Sidney, Jackson Center, and Botkins."

April 27, 1937  
Allen County  
lat 40.7°, long -84.0°  
MMI = III  
M = 3.1

This earthquake represented continued activity in the Western Ohio Seismogenic Zone following the main shocks of March 2 and March 9, 1937. Bradley and Bennett (1965), citing articles in the *Shelby County Democrat* and the *Sidney Daily News*, stated: "Slight shock felt in Sidney and Anna."

May 2, 1937  
Allen County  
lat 40.7°, long -84.0°  
MMI = IV  
M = 3.1

This earthquake appears to be the last of significant felt events in the Western Ohio Seismogenic Zone following the main shocks of March 2 and March 9, 1937. Bradley and Bennett (1965), citing articles in the *Shelby County Democrat* and the *Sidney Daily News*, stated: "Shock

felt at Sidney, Anna, Jackson Center, and surrounding communities. The tremor lasted a few seconds and no damage was reported."

October 17, 1937  
Hamilton County  
lat 39.1°, long -84.5°  
MMI = III  
M = 2.9

Bradley and Bennett (1965), citing an article in the *Cincinnati Enquirer*, stated: "Shock felt by many people in suburbs of Cincinnati."

March 18, 1939  
Shelby County  
lat 40.4°, long -84.0°  
MMI = IV  
M = 3.3

Bradley and Bennett (1965), summarizing articles in the *Shelby County Democrat* and the *Sidney Daily News*, stated: "A number of persons in Sidney reported they felt and heard an earthquake." Seeber and Armbruster (1991) list two shocks, approximately eight hours apart, on this day, the second being the largest.

June 18, 1939  
Shelby County  
lat 40.3°, long -84.0°  
MMI = IV  
M = 3.1

Bradley and Bennett (1965), citing articles in the *Shelby County Democrat* and the *Sidney Daily News*, stated:

*Felt at Botkins, Jackson Center, Sidney, and Wapakoneta. Strongest at Anna. Caused much excitement but no damage. Bottles and dishes rattled. Rumbling noise reported.*

July 9, 1939  
Shelby County  
lat 40.3°, long -84.0°  
MMI = II  
M = 2.5

Bradley and Bennett (1965), citing the U.S. Coast and Geodetic Survey's United States earthquakes (Bodle, 1939), reported a "slight shock at Anna."

June 16, July 28, August 15, August 20, 1940  
Ashland County  
lat 40.9°, long -82.3°  
MMI = IV  
M = 3.1

Bradley and Bennett (1965) repeated an account in Neumann (1942) of a series of four events near Nankin, Richland County:

*On a farm north of Nankin a series of tremors, thought to be of seismic origin, continued at intervals for several months. This event (June 16) was the strongest. People were awakened by the shock.*

March 9, 1943  
Lake County  
lat 41.63°, long -81.31°  
MMI = V  
M = 4.7

At the time, this was the largest earthquake to occur in northeastern Ohio. Stover and Coffman (1993) briefly summarized the event:

*An earthquake broke windows and dishes and cracked plaster in the Lake Erie area. The widely felt shock was reported in Michigan, New York, Ohio, Pennsylvania, and Canada.*

Dewey and Gordon (1984) relocated the epicenter and recalculated the magnitude. Their results moved the epicenter from offshore, beneath Lake Erie, to central Lake County. They computed the magnitude as 4.5. Stover and Coffman (1993) assigned a magnitude of 4.7, based on the felt area.

November 13, 1944  
Shelby County  
lat 40.4°, long -84.4°  
MMI = III  
M = 4.1

Bradley and Bennett (1965), citing an article in the *Shelby County Democrat*, stated: "Epicenter apparently near Anna and Botkins. No damage was caused by shock, which lasted 7 seconds. Earthquake reported felt as far away as Indianapolis, Indiana." Bodle (1946) indicated that it was felt in Ohio at Beaver Dam, Findlay, Kenton, Lakeview, Lima, Sidney, and Van Wert. The intensity assigned to this event by Bradley and Bennett (1965) has been followed by later authors; however, the felt area and intensity, and

consequent felt-area magnitude, seem to be anomalous. This event requires further research.

January 18, 1948  
Lucas County  
lat 41.7°, long -83.6°  
MMI = III  
M = 2.9

Bradley and Bennett (1965), summarizing an article in the *Toledo Blade*, stated: "One family awakened by tremor in suburbs of Toledo. Another reported sound similar to an explosion. A cement floor was reported cracked and cracks were found in the ground."

April 20, 1950  
Montgomery County  
lat 39.8°, long -84.2°  
MMI = IV  
M = 3.1

Bradley and Bennett (1965), citing an article in the *Bellefontaine Examiner*, reported: "Sudden earth tremors were felt in Dayton and surrounding areas. Some dishes and windows were broken. Possibly an earthquake, but more probably a low flying aircraft."

The *Cincinnati Times Star* reported in the April 21 edition that shaking was felt within a 25-mile radius of Dayton and speculation on the cause ranged from atmospheric disturbances to an exploding flying saucer. The event did not register on seismographs at John Carroll University in Cleveland or Xavier University near Cincinnati.

The *Columbus State Journal* reported on April 21 that the shock was felt from Troy to Miamisburg and that Dayton newspaper and radio-station offices were flooded with phone calls. Broken windows were reported in Dayton but an article in the *East Liverpool Review* said that a *Dayton Journal Herald* reporter could not locate any cracked windows. This same newspaper contained statements from Wright-Patterson Air Force Base and Monsanto's atomic research facility at Miamisburg denying any involvement in the tremor.

The *Hillsboro Press-Gazette* reported on April 25 that another shock occurred on April 21 at 12:15 p.m. local time. This shock appeared to be

somewhat smaller than the one at 11:30 a.m. on April 20, and appeared to be centered east of Dayton, in the vicinity of Wright-Patterson Air Force base.

Newspaper reports centered on an atmospheric explanation for the events, either natural or cultural, and seem to dismiss the possibility of an earthquake based on the fact that neither event was recorded at Ohio's two seismic stations, in Cincinnati and Cleveland. However, instruments used at these stations in 1950 may have lacked the sensitivity to clearly record an earthquake in the 3-magnitude range, considering their distance from the felt area.

Wright-Patterson Air Force Base is located near Dayton and there is a possibility that this event was a sonic boom created by aircraft. Dr. Jeff Underwood of the U.S. Air Force Museum, in Dayton, indicated that the F-86 aircraft based at Wright-Patterson in 1950 were not capable of supersonic speed in level flight but could achieve this in a dive. He indicated that there are no surviving records indicating whether or not a sonic boom occurred on April 20 and 21, 1950. However, on May 18, 1953, Jacqueline Cochran was the first woman to break the sound barrier piloting an F-86 Sabre jet in California, indicating that this aircraft, at least by 1953, was capable of supersonic flight. The origin of these events remains equivocal.

December 3, 1951  
Lake County  
lat 41.6°, long -81.4°  
MMI = IV  
M = 2.9

Weston Geophysical Corporation (1979) investigated this event and events reported in the same area by Bradley and Bennett (1965) on December 7 and December 20. The Weston report indicates that they could not find newspaper articles pertaining to the latter two events and that the seismograms from John Carroll University showed no hint of events at these dates and times. The December 3 event was widely reported in newspapers in northeastern Ohio.

From *Cleveland News*, December 3, 1951:

*A light tremor shook houses and frightened residents over a wide area of eastern Cuyahoga County and the western portion of Lake County early today but apparently caused no damage.*

*The tremor, which was recorded at 2:02 a.m., centered around Willoughby, but was*

*felt throughout an area 10 to 15 miles in diameter on Lake Erie's south shore, according to police and the Rev. Henry F. Birkenhauer, seismologist at John Carroll University.*

*Hundreds of calls from residents in Kirtland, Wickliffe, Willowick and Bratenahl, awakened as their homes shook and dishes and windows rattled, were received by police. Within an hour after the tremor Willoughby police received 100 calls. Eastlake and Euclid police said the tremor seemed to miss their communities.*

Henry F. Birkenhauer, S. J., director of the John Carroll University Seismological Observatory, surveyed postmasters throughout the area about the earthquake and its effects in their communities. These reports indicate that the event was felt most strongly in Eastlake, Mentor, Mentor-on-the-Lake, and Willoughby. Lesser effects were reported from Bratenahl, Burton, and Painesville. The felt reports suggest an epicenter similar to instrumentally located events in 1999 and 2006, which were offshore between Eastlake and Mentor-on-the-Lake. Felt reports from the 1951 event, compared with the earthquakes of 1999 (2.8) and 2006 (2.6), suggest that it may have been in the low 3-magnitude range.

June 20, 1952  
Perry County  
lat 39.64°, long -82.02°  
MMI = VI  
M = 3.9

Bradley and Bennett (1965), citing accounts in the *Cleveland Press* and *Zanesville Times Recorder*, reported:

*Shock felt over a 20 mile radius, with strongest effects at Zanesville. The tremor awoke most of the people in the area, as dishes were rattled, pictures shaken and doors thrown open. Disturbance lasted from five to ten seconds.*

An article in the *Columbus Dispatch*, June 23, 1952, reported:

*The mild quake was felt strongest in the vicinities of Zanesville, New Lexington, Moxahala, and as far as Athens, some 50 miles south of Zanesville. There were only a few scattered reports from the Columbus area.*

Murphy and Cloud (1954) reported:

VI. At Zanesville an old chimney reported toppled. Coal toppled from cars at Corning, intensity V. Intensity IV at Buchtel, Cumberland, Hemlock, Junction, Lancaster, Moxahala, Nashport, Somerset, and above two cities the majority of the populace observed disturbed objects; windows and dishes rattled, pictures shook, and doors thrown open.

Dr. Edward J. Walter, assistant director of the John Carroll University observatory, studied this event and compiled felt reports through a post-card survey of postmasters in the probable felt area, in addition to soliciting instrumental data from regional seismic stations. These data are now archived at the Ohio Earthquake Information Center. Dr. Walter noted an elliptical felt area with an east-west major axis of 65 miles and a north-south minor axis of approximately 50 miles. He indicated that the strongest intensity, with one report of cracked plaster, was V, at Roseville.

May 7, 1953  
Perry County  
lat 39.7°, long -82.1°  
MMI = IV  
M = 2.7

Murphy and Cloud (1955) stated:

Crooksville, Ohio. Startled many residents. Windows and dishes rattled; buildings quivered in downtown area; sounded like a distant explosion. Ohio Power buildings shook. Also felt on a hill a mile south of the power building and in Roseville.

June 12, 1953  
Lucas County  
lat 41.7°, long -83.6°  
MMI = IV  
M = 3.5

Murphy and Cloud (1955) reported:

*Toledo, Ohio. Pictures knocked off walls in Toledo and suburbs; hundreds of telephone calls to police and newspapers. Houses shaken in Adams, Springfield, and Sylvania.*

May 26, 1955  
Cuyahoga County  
lat 41.29°, long -81.57°  
MMI = V  
M = 3.3

Bradley and Bennett (1965), citing articles in the *Cleveland Plain Dealer* and the *Cleveland Press*, stated:

*Shock seems to have been centered in southeastern suburbs of Cleveland, near Aurora. Houses were jolted, doors, windows and dishes rattled and pictures were shaken from walls. A rumbling noise accompanied the tremor.*

Murphy and Cloud (1957) stated:

*Southeastern suburbs of Cleveland, Ohio. Recorded on the seismograph at John Carroll University. Newspaper and police stations flooded with calls. Felt indoors by many; alarmed few at Bedford. Buildings creaked; doors, windows, and dishes rattled. Some reported subdued rumbling sounds. Motion trembling.*

At Chagrin Falls, they reported:

*Felt indoors by many. Windows, doors and dishes rattled; buildings creaked; pictures knocked askew. Many thought an explosion had occurred at a fireworks or powder factory. Motion trembling.*

At Solon, they reported:

*Felt indoors by many. Windows, doors, and dishes shook; building creaked; loose object rattled. Moderately loud sounds heard. Motion trembling.*

At Geauga Lake they reported: "Felt indoors by many. Walls creaked; loose objects rattled. Some compared the sound to a blast." At Richmond Heights, they reported: "Felt like a truck had hit building." Seeber and Armbruster (1993) relocated this event to the current coordinates.

The *Cleveland News* on May 26, 1955, reported that the Cleveland suburbs of Bedford, Garfield Heights, Maple Heights, Mayfield, Pepper Pike, Richmond Heights, Shaker Heights, Solon, and Warrensville filed police reports of explosions, shaking, and rumbles. In notes now archived at the Ohio Earthquake Information Center, Dr. Edward J. Walter, assistant director of the John Carroll University Seismological Observatory, reports that the S-P arrivals from this event indicated a distance of 12.6 miles from the observatory, which is consistent with a location in southeastern Cuyahoga County.

June 29, 1955  
Portage County  
lat 41.39°, long -81.41°  
MMI = IV  
M = 2.7

Bradley and Bennett (1965) stated: "Second earthquake occurred in suburbs of Cleveland near Aurora. Many were alarmed as houses rattled and a rumbling sound was heard."

Murphy and Cloud (1957) reported:

*Southeastern suburbs of Cleveland, Ohio. Felt by and alarmed many. Houses vibrated. Rumbling sounds heard by many. At Geauga Lake felt by many indoors. Frightened few. Some compared the sound to a blast. Field investigations at Roundup Lake Park in Portage County by the John Carroll University revealed disturbance of Lake bottom level, increased water volume in Lake and sanding of well.*

They indicated that the event was felt by many, with doors, windows, and dishes rattling at Aurora, Bedford, Chagrin Falls, Macedonia, Maple Heights, and Solon. The event was felt at lesser intensities at Beachwood, Bedford Heights, Bentleyville, Cleveland Heights, Hunting Valley, Moreland Hills, Orange Village, Pepper Pike, Shaker Heights, and Willoughby. S-P times recorded by Dr. Edward J. Walter at the John Carroll University Seismological Observatory indicated an epicentral distance of 12.6 miles from the observatory. Felt reports suggest that this event may have been farther south and east of the earthquake on May 26, 1955. Seeber and Armbruster (1993) relocated this event.

January 27, 1956  
Shelby County  
lat 40.5°, long -84.0°  
MMI = V  
M = 3.7

Brazeo and Cloud (1958) stated:

*West central Ohio. Felt by, awakened, and frightened many at Anna, Botkins, Elmview (near Lima), Kettlersville, Lima, Port Jefferson, Quincy, and Sidney. Building shook; windows and dishes rattled. Disturbed objects observed by several. Felt by many at DeGraff, Middleburg, Saint Marys, Wapakoneta (few alarmed), and West Liberty where buildings creaked; loose objects rattled. Felt with intensity III at Bellefontaine and Fort Wayne,*

*Ind. Recorded by the seismograph at John Carroll University and the amateur seismograph of Jacob E. Zint at Wapakoneta.*

The S-P time at the John Carroll University Seismological Observatory indicated a distance of 166 miles from the observatory to the epicenter. A second shock occurred an hour after the first.

July 23, 1957  
Brown County  
lat 38.7°, long -83.8°  
MMI = III  
M = 2.9

Bradley and Bennett (1965), citing an article in the *Cleveland Press*, stated: "Shock at Ripley was recorded by John Carroll University. Two distinct shocks jarred buildings, but no damage was reported."

February 22, 1961  
Seneca County  
lat 41.2°, long -83.3°  
MMI = V  
M = 3.7

Lander and Cloud (1963) reported this event.

*Amsden—Felt by, awakened, and alarmed many. Buildings creaked; loose object rattled. Rapid onset; trembling motion. Subterranean sounds heard by many. Arcadia—Felt by, awakened, and alarmed many. Buildings shook; dishes and loose objects rattled. Sounded like a sonic boom. Fostoria—Felt by and awakened nearly all. Police and newspaper switchboards swamped with calls from alarmed citizens. Pictures knocked askew. Buildings shook; dishes, windows, and doors rattled. Abrupt onset; bumping motion. Sounded like a sonic boom.*

Reports of lesser intensity were reported from Adrian, Bascom, Carey, Findlay, Fremont, Hoytville, Mount Blanchard, and Wayne. The event was slightly felt at Green Springs, New Riegel, Ottawa, Tiffin, and West Millgrove.

Bradley and Bennett (1965) reported: "Shock felt in Findlay, where citizens reported mild shaking which lasted about two minutes. Recorded at John Carroll University."

April 8, 1967  
Fairfield County  
lat 39.65°, long -82.53°  
MMI = V  
M = 3.7

Von Hake and Cloud (1969) reported:

*Felt over approximately 4,000 square miles of central and southeastern Ohio. The felt area extended from the Columbus and Sunbury areas southeast to Newark, Hebron, Lancaster, and Athens. In the central section of Columbus, four groundline windows were broken and minor plaster cracks were observed in an apartment house. Intensity V effects were also noted at Hebron and Lancaster; intensity IV at Athens (northwest of), Bexley, Logan, Newark, Pleasantville, and Sunbury.*

An article in the April 8, 1967, *Columbus Dispatch* reported:

*The tremor shook many Columbus-area residents from their sleep and shook buildings for approximately 75 miles to the southeast. A dispatcher at the Hebron post of the State highway Patrol reported a 500-pound desk in his office started 'bouncing like a toy' when the quake struck.*

July 26, 1968  
Shelby County  
lat 40.4°, long -84.2°  
MMI = III  
M = 3.0

A small earthquake, which at first seemed to receive little media attention, was recorded on a borehole seismometer at the University of Michigan and on an instrument at Xavier University's Milford, Ohio station. A description of the event was published by Willis and Wilson (1970). They noted that an article in the *Sidney Daily News*, published after their inquiry, prompted a number of telephone calls and letters to the newspaper, which allowed them to determine the intensity and felt area. Although they were able to instrumentally determine the body wave magnitude and origin time, too few stations recorded the event to provide a precise instrumental location.

September 29, 1974  
Wood County

lat 41.21°, long -83.49°  
MMI = III  
M = 3.0

An article in the *Columbus Dispatch*, September 30, reported: "The tremor was felt in the Findlay, Tiffin and Bowling Green areas." The U.S. Geological Survey (Coffman and Stover, 1976) noted intensity II at Bowling Green, Findlay, Fostoria, and Tiffin.

February 3, 1975  
Sandusky County  
lat 41.3°, long -83.2°  
MMI = IV  
M = 3.3

The U.S. Geological Survey (Coffman and Stover, 1977) indicated:

*Newspaper reports stated that residents of Seneca and Sandusky Counties felt their homes shaken by the tremor. Intensity IV at Burgoon, Fremont, Melmore, Millersville, Republic, Tiffin. Intensity III at Lakeside, Marblehead.*

February 16, 1975  
Gallia County  
lat 38.88°, long -82.35°  
MMI = IV  
M = 3.0

An article in the *Athens Messenger* on February 17, 1975, reported:

*The owner of a trailer home one mile north of Rio Grande reported feeling the tremor, and sheriff's offices in Jackson and Gallia counties reported receiving calls. None of the calls involved damage, and no other reports on the tremor came from the surrounding area or outside the state.*

The *Columbus Dispatch* on February 17, 1975, added: "Sheriff's deputies said numerous calls were received in Gallia County and southern Jackson County from persons reporting a tremor which they described as like a sonic boom."

Coffman and Stover (1977) reported intensity IV at Addison, Coalton, Oak Hill, Rio Grande, Thurman, and Wilkesville, Ohio, and Point Pleasant, West Virginia. Intensity III at Jackson and Vinton, Ohio. Intensity II at Danville, 1.6 km north of Rio Grande (press report), South Webster. Felt in

Jackson and Gallia Counties south to the Lawrence County line (press reports).

June 17, 1977  
Mercer County  
lat 40.57°, long -84.67°  
MMI = VI  
M = 3.3

This comparatively small-magnitude earthquake (3.2 mbLg) generated Modified Mercalli Intensities as high as VI and caused minor-to-moderate damage in the epicentral area of the Anna Seismogenic Zone near Celina. Coffman and Stover (1979) summarized the event—the first to occur in this area after establishment of the Anna Seismic Network by the University of Michigan (Mauk, 1977). The earthquake was felt over an area of 550 square kilometers in western Ohio, from Celina south to Chickasaw, west to Fort Recovery, and north to Rockford. At Celina, a foundation and sidewalk cracked. At Coldwater, a sidewalk cracked, plaster cracked, fallen plaster, cracked foundations, a mobile home moving slightly on its foundation, and changes in water wells were observed. At Fort Recovery, a water tank cracked and stone fences were cracked. At Rockford, sidewalks cracked, hairline cracks appeared in exterior walls, and a ceiling-light fixture was loosened.

At Celina, Coldwater, Montezuma, Rockford, and St. Henry, residents were frightened, buildings trembled, heavy furniture shifted, and some pictures were knocked from walls. Some of the high intensities and damage may be related to amplification effects of unconsolidated sediments in the vicinity of Grand Lake St. Marys. This instrumentally located earthquake emphasizes that some historic “Anna area” earthquakes may not have been centered directly at Anna.

October 4, 1980  
Clark County  
lat 39.80°, long -83.75°  
MMI = Not Computed  
M = 2.0

This small earthquake was detected and located by the Anna Seismic Network. Although it was on the lower threshold of being felt, no felt reports were recorded.

January 22, 1983  
Lake County

lat 41.854°, long -81.191°  
MMI = Not Computed  
M = 2.7

The U.S. Geological Survey (Stover, 1986b) reported a small earthquake beneath Lake Erie, offshore from Painesville-on-the-Lake. Although this earthquake was large enough to have been felt (2.7 mbLg) onshore, no reports were received. In part, this may be because the event occurred at 2:46 a.m. EST, when most residents would have been asleep.

July 5, 1983  
Shelby County  
lat 40.43°, long -84.10°  
MMI = Not Computed  
M = 2.1

This small earthquake was recorded by the Anna Seismic Network (Ruff and others, 1994). Although the event was at the lower range of being felt, no reports were received.

January 14, 1984  
Lucas County  
lat 41.67°, long -83.45°  
MMI = IV  
M = 2.6

Stover (1988) lists this event as intensity IV at Harbor View and Oregon; intensity III at Walbridge; and felt in the eastern part of Toledo. The earthquake was recorded by the Anna Seismic Network (Ruff and others, 1994), who determined the coordinates and magnitude.

January 31, 1986  
Lake County  
lat 41.65°, long -81.16  
MMI = VI  
M = 5.0

This damaging earthquake is the largest recorded in northeastern Ohio and remains the most-studied earthquake in the state. Although damage was moderate from the event, its occurrence near midday on a Friday, in a heavily populated region, a large felt area, and its proximity to the Perry Nuclear Power Plant at North Perry created enormous public, media, and scientific interest. Approximately 30 seismologists from a variety of academic institutions and government agencies came to Ohio to study intensities and damage and to deploy a dense

network of portable seismographs in order to record aftershocks and better define the parameters of the event. Publications include: Hansen (1986), Stover (1986a), Ahmad and Smith (1988), Nicholson and others (1988), and Stover and Coffman (1993).

The 5.0-magnitude earthquake was felt in 11 states and parts of Ontario, Canada. Maximum intensities in the epicentral area were in the VI–VII range and brief-duration accelerations of 0.18 g were recorded at the Perry Nuclear Power Plant, located about 17 km from the epicenter. Two aftershocks were felt, of only 13 recorded in the 2.5 months following the main shock. Studies of the focal mechanisms of the aftershocks indicated that the nearly vertical seismogenic fault was oriented NNE and motion was predominantly strike-slip. Later studies suggested that this fault was related to a significant NNE-oriented linear trend visible in basement rocks on magnetic-anomaly maps. This feature was named the Akron Magnetic Lineament by Aggarwal (1987). Focal depths of the aftershocks ranged from 2 to 6 km.

Stover (1986a) did an extensive intensity/damage survey of the earthquake. He noted that damage was anomalously low for this event as compared to the 1929 Attica, New York, earthquake and the March 9, 1937 Anna, Ohio, earthquake, both of which had comparable felt areas and only slightly higher magnitudes. Although detailed quantitative comparisons of the intensities and damage of these respective earthquakes with thickness and composition of surficial sediments in the epicentral regions has not been done, we would suggest that these would be important factors. Much of the epicentral area of the Lake County earthquake is characterized by thin surficial sediments overlying Paleozoic bedrock. Highest damage from the 1937 Anna earthquake was in an area of very thick unconsolidated sediment.

Most damage was in Lake and Geauga Counties and indicated Modified Mercalli Intensities in the high VI range. Selected damage reports from Stover (1986a) are given in the following paragraphs.

#### *Lake County*

Grand River—A 6-inch water main was broken at a joint; wood panels came loose and cracks enlarged at Western Reserve Montessori School; other reports of cracked plaster and merchandise thrown off store shelves.

Kirtland—Chimneys, basement floors, and cement-block basement walls cracked; wall and

ceiling plaster fell at Kirtland Temple visitor center; suspended ceiling fell at Lakeland Community College.

Madison—Cement-block walls were cracked and ceiling tiles fell at Madison High School; cracked chimneys with bricks falling from some, and cracks in basement floors.

Mentor—Cracked walls at three schools; ceiling tiles fell and merchandise thrown off shelves in grocery store; ceiling tiles fell at shopping mall; window broken and six windows cracked at Catholic church; 15 buildings damaged according to press reports.

Painesville—Nineteen windows cracked or broken and large crack in stairwell at Lake Erie College; cracks in walls and ceiling of high school; ceiling tiles fell at hospital; damaged chimneys, cracked plaster, cracked basement walls and a fireplace front reported.

Willoughby—Broken windows, cracks in plaster walls; cracked cement-block foundation; some broken glassware; merchandise thrown off store shelves; cracks in street.

#### *Gauga County*

Bainbridge—Chimney shifted and walls cracked at school.

Chardon—Plaster fell at courthouse annex; chimneys cracked; building foundations cracked; double plate-glass window broken at a home; merchandise thrown off store shelves.

Leroy—Cracked wall and broken windows at elementary school; several cracked chimneys and one fireplace; bricks fell from one chimney.

Middlefield—Cracked chimneys; cracked reinforced concrete wall; hairline cracks in plaster walls; cracked windows; a report of visible waves on ground.

In addition to damage reports from other communities in these two counties, damage reports at Bowling Green in Wood County (approximately 200 km from epicenter) included cracks in several buildings. Reports of cracks in plaster and chimneys and some broken windows were received from Albion, Erie County, and Linesville, Crawford County, Pennsylvania.

There was a suggestion that the Chardon earthquake may have been triggered by two Class I, deep injection wells located about 12 km from the epicenter. Nicholson and others (1988) studied this issue, along with other aspects of this

earthquake, and concluded that the probability was low that the earthquake had been triggered by the well fluid. Their conclusion was based on three points: (1) seismicity, including a 4.7-magnitude earthquake, long preceded injection wells or mining activities in the area; (2) the main shock was at a depth of about 6 km, far below the injection depth of 1.8 km; (3) lack of swarms of aftershocks as is typical of induced earthquakes.

February 7, 1986  
Lake County  
lat 41.65°, long -81.16°  
MMI = Felt  
M = 2.5

This was an aftershock of the January 31 main shock. This event was felt at Chardon, Hambden, Mentor, and Painesville.

July 12, 1986  
Auglaize County  
lat 40.55°, long -84.39°  
MMI = VI  
M = 4.5

This was the second damaging earthquake in Ohio in 1986 (see January 31); however, this event was in the Western Ohio Seismogenic Zone, which, historically, has been the most active in the state, and it was the largest in the area since the Anna earthquakes of 1937. The Anna Seismic Network recorded the event, which was described in detail by Schwartz and Christensen (1988), who determined that the earthquake occurred on the northwest-southeast-oriented Anna-Champaign fault. This fault is a near-vertical strike-slip fault and the movement was left lateral. They computed the focal depth of the earthquake to be 5 km. The instrumental epicenter, determined by the nine-station Anna Seismic Network, was at St. Marys in Auglaize County. No aftershocks followed the main shock until four months later.

Stover and Brewer (1994) presented detailed information on intensities and damage and an isoseismal map of the earthquake, which was felt throughout a contiguous area of 85,500 km<sup>2</sup> that included much of Ohio and portions of Indiana, Kentucky, Michigan, and a few places in West Virginia. The highest intensities were VI. Stover and Brewer (1994) summarized the damage reports obtained by postcard canvas and press reports.

Anna—A fireplace cracked; chimneys cracked; interior walls sustained hairline cracks; a few small objects overturned and fell; shaking was strong and felt by and awakened many people.

Minster—Bricks fell from chimneys; plaster walls sustained hairline cracks; a few small objects overturned; hanging pictures fell; shaking was strong and awakened many people.

New Bremen—Chimneys cracked; a few glassware items or dishes broke; a few windows cracked; a few small objects overturned and fell; buildings shook moderately.

St. Marys—Walls cracked at a hospital and a few bricks fell from the top of the chimney at the Goodyear plant. A few items were shaken off store shelves; a few small objects overturned and fell; hanging pictures swung out of place; buildings shook moderately; felt by and awakened many people.

Minor damage was reported from the following Ohio communities: Batavia, Botkins, Chillicothe, Croton, Danville, Grelton, Harrod, Kettlersville, Lafayette, Lima, Manchester, Maria Stein, Mendon, Montezuma, Napoleon, Newtonsville, Owensville, Pickerington, Quincy, Ripley, Roosevelt, Spencerville, Uniopolis, Urbana, Van Wert, Versailles, Wapakoneta, Waynesville, West Mansfield, West Salem, and Yorkshire. Minor damage also was reported at the following communities in Kentucky: Botkins, Mount Olivet, and Silver Grove.

July 13, 1987  
Ashtabula County  
lat 41.903°, long -80.758°  
MMI = IV  
M = 3.8

This 3.8-magnitude earthquake was the first in a series of minor-to-moderate earthquakes to strike Ashtabula, including 12 aftershocks above 2.0 magnitude, from July 13 to July 16. The main shock was felt with MMI IV at Ashtabula, Conneaut, Kingsville, and North Kingsville. It also was felt at Dorset and Rome, and in western Erie County, Pennsylvania. These events, including a number of aftershocks less than 2.0 magnitude, were recorded by the John Carroll University Seismic Network. Prior to this event, Ashtabula had not experienced any earthquakes with epicenters near the town, or in the county.

J. G. Armbruster and Leonardo Seeber of Lamont-Doherty Earth Observatory deployed

portable instruments in the epicentral area for 10 days, beginning two days after the main shock (Seeber and Armbruster, 1993). During this period, they recorded 36 small earthquakes that clustered in a narrow, east-west striking vertical zone about 1.5 km long and extending from depths of 1.7 to 3.5 km. These hypocenters were about 0.7 km from a Class I injection well that began pumping fluids to a depth of about 1.8 km in July, 1986. This depth is the approximate depth of the interface of crystalline basement rocks with the overlying Mt. Simon Sandstone, the reservoir into which fluids were being pumped. Seeber and Armbruster (1993) concluded that the 1987 Ashtabula earthquake swarm had been triggered by injection-well fluids that reached a previously unknown basement fault. Focal mechanisms for these events determined that the fault was near-vertical left-lateral strike-slip with little or no vertical component of movement.

Earthquakes have occurred intermittently at or near Ashtabula from 1987 through 2001, including a number of felt events (Hansen, M. C., e. al., 2001). These events were instrumentally recorded by the John Carroll University Seismic Network from 1987 through mid-1992.

March 31, 1988  
Portage County  
lat 41.313°, long -81.046°  
M = 2.8  
MMI = Not computed

A small earthquake was recorded by the John Carroll University Seismic Network in northeastern Portage County, near the community of Nelson.

June 27, 1988  
Lake County  
lat 41.818°, long -81.229°  
M = 2.7  
MMI = Not computed

A small earthquake was recorded by the John Carroll University Seismic Network beneath Lake Erie, offshore from Painesville-on-the-Lake.

October 22, 1988  
Shelby County  
lat 40.45°, long -84.11°  
M = 2.2  
MMI = Not computed

A small earthquake was recorded west of Jackson Center, Shelby County, by the Anna Seismic Network.

December 25, 1988  
Lake County  
lat 41.840°, long -81.018°  
MMI = Felt  
M = 2.4

A small earthquake was recorded by the John Carroll University Seismic Network east of North Madison. This event was felt in North Madison and Madison-on-the-Lake.

December 28, 1988  
Geauga County  
lat 41.636°, long -81.166°  
MMI = Felt  
M = 2.8

A small earthquake was centered in northern Hambden Township, Geauga County, just south of the Lake County line. It was reported to have been felt in Chardon and Mentor. This event was close to the epicenter of the January 31, 1986, earthquake that was felt over a multistate area.

August 1 and August 3, 1989  
Ashtabula County  
lat 41.893°, long -80.752°  
MMI = Felt  
M = 2.8, 2.9  
M = 2.2

Two small, felt earthquakes, 38 minutes apart, were recorded by the John Carroll University Seismic Network at Ashtabula on August 1. A smaller event, probably not felt, was recorded on August 3. These events were several kilometers south of the 1987 earthquake swarm near a Class I injection well on the east side of Ashtabula.

1990  
Ashtabula County  
January 1: lat 41.902°, long -80.799°; M = 2.2  
July 24: lat 41.902°, long -80.879°; M = 2.3  
September 26: lat 41.902°, long -80.749°; M = 2.3  
November 18: lat 41.902°, long -80.790°; M = 2.3  
MMI = Not felt

Four small earthquakes, none of which were reported to have been felt, were recorded by the John Carroll University Seismic Network. The instrumental locations for these events are in an east-west alignment, west of the Class I injection well on the east side of Ashtabula.

June 4, 1990  
Hancock County  
lat 41.080°, long -83.510°  
MMI = IV  
M = 2.3

The Anna Seismic Network recorded a small earthquake northeast of Findlay. It was reported to have been felt (IV) at Findlay and (III) at Bloomdale and Vanlue.

January 27, 1991  
Lake County  
lat 41.610°, long -81.594°  
MMI = V  
M = 3.5

An earthquake centered north of Mayfield Heights was recorded by the John Carroll University Seismic Network and widely felt in Cleveland and the greater Cleveland area. The U.S. Geological Survey indicated MMI V at Brecksville, Broadview Heights, and Cleveland; IV at Elyria, Highland Heights, Lakewood, Lorain, and Munroe Falls; III at Chardon, Madison, Mentor, North Olmsted, Parma, Solon, and Twinsburg. Wire service press reports indicate that the earthquake was felt as far west as Vermillion and east to Willoughby. No damage was reported.

March 12, 1991  
Cuyahoga County  
lat 41.327°, long -81.361°  
M = 2.3  
MMI = Not felt

The John Carroll University Seismic Network recorded a small earthquake centered in northwest, Portage County, between Aurora and Remindersville. No felt reports were received for this event.

October 13, 1991  
Lake County  
lat 41.711°, long -81.054°  
M = 2.0  
MMI = Not felt

A small earthquake was recorded by the John Carroll University Seismic Network, which was centered north of Thompson, Geauga County, just south of the Lake County line. No felt reports were received for this event.

March 15, 1992  
Lake County  
lat 41.817°, long -81.226°  
MMI = IV  
M = 3.4

The John Carroll University Seismic Network and U.S. Geological Survey stations recorded an earthquake centered beneath Lake Erie, just offshore from Painesville-on-the-Lake. A smaller (2.2) aftershock occurred about eight minutes after the main shock. The main shock was widely felt in a several-county area, but no damage was reported. The U.S. Geological Survey noted MMI IV at Ashtabula, Columbia Station, Concord, Conneaut, Madison, North Perry, and Unionville; III at Austinburg, Berea, Fairport Harbor, Geneva, Grand River, and Painesville.

1992  
Ashtabula County  
MMI = Felt  
March 26: lat 41.870°, long -80.870°; M = 2.5  
March 28: lat 41.860°, long -80.910°; M = 2.9  
March 31: lat 41.860°, long -80.860°; M = 2.5  
April 7: lat 41.833°, long -80.850°; M = n/a

The John Carroll University Seismic Network recorded these four earthquakes, centered west of Ashtabula. The three March earthquakes, centered beneath Lake Erie, just offshore from the west side of Ashtabula, were felt in this community, especially in the harbor area. The April event was located onshore, near Saybrook, just south of the March events. There was speculation in the *Ashtabula Star Beacon* that the earthquakes may have been triggered by fluids from a Class I injection well on the east side of Ashtabula.

July 14, 1992  
Wood County  
MMI = Felt  
Lat 41.2, long -83.7  
M = 2.0

Dr. Donald Stierman of the University of Toledo (station UTLO) recorded a small earthquake and received two felt reports from individuals in North Baltimore, southern Wood County. Instrumental

data were insufficient to precisely locate the epicenter, which has been placed at North Baltimore on the basis of felt reports.

October 4, 1992  
Wood County  
lat 41.4°, long -83.5°  
MMI = Felt  
M = 2.5

A small earthquake was felt in Bowling Green. Press reports indicated that windows and dishes rattled throughout the community. A few people reported that it sounded like a loud explosion or sonic boom. The seismograph station at the University of Toledo was not operating at the time of the event and the Anna Seismic Network had closed a few months prior to this earthquake. The event was too small to be recorded at distant U.S. Geological Survey stations in operation at that time. The location and magnitude for this event are, therefore, noninstrumental.

October 10, 1993  
Lucas County  
lat 41.65°, long -83.50°  
MMI = Felt  
M = 2.0

Dr. Donald Stierman of the University of Toledo (station UTLO) recorded a small earthquake at the distance indicated by three felt reports west of St. John's Jesuit High School in Toledo. The coordinates assigned to this event are based on the UTLO record and the felt reports; however, this is a noninstrumental location because of the lack of a sufficient number of seismographs to triangulate instrumental coordinates.

October 16, 1993  
Geauga County  
lat 41.70°, long -81.01°  
MMI = IV  
M = 3.6

This earthquake, centered northeast of Thompson, near the Lake-Ashtabula County line, was felt (IV) at Madison and Unionville, and at a lesser intensity at Perry. The event was recorded and located by the Geological Survey of Canada. All seismograph stations in Ohio, except for the intermittently operating station at the University of Toledo, had closed the previous year.

November 9, 1993  
Wood County  
lat 41.4°, long -83.5°  
MMI = Felt  
M = 2.0

A small, poorly located earthquake was felt in Bowling Green and Maumee, according to a report in the *Toledo Blade*. The University of Toledo seismic station recorded the event.

April 4, 1994  
Shelby County  
lat 40.4°, long -84.0°  
MMI = Felt  
M = 2.9

A small earthquake was felt in Anna and Jackson Center, Shelby County, according to press reports (*Dayton Daily News*, April 6, 1994). The event was recorded by a University of Kentucky Seismic Network station at Flemingsburg, Kentucky, but is poorly located because of the paucity of other regional seismic stations in operation at the time.

July 9, 1994  
Pike County  
lat 39.045°, long -83.294°  
MMI = III  
M = 2.5

A small earthquake was recorded by four stations of the Kentucky Seismic Network and instrumentally located in southwestern Pike County, just north of the Adams County line. Sheriff's departments in Adams, Highland, and Pike Counties received numerous phone calls, as did the newspaper office in West Union and the post office in Sinking Spring. A citizen, residing near Latham, Pike County, reported to the ODNr Division of Geological Survey that it "felt like the road waded" and that it sounded "like a double boom from a jet or a shot in a coal mine." Another citizen, residing between Idaho and Latham, Pike County, reported a thud and a rolling feeling that appeared to be from south to north.

January 12, 1995  
Richland County  
lat 40.80°, long -82.68°  
M = 3.3  
MMI = Not computed

The U.S. Geological Survey recorded an event, imprecisely located, near the western Richland County line, just east of Crestline, Crawford County. There was informal speculation that the event may have been a mining blast as there were no felt reports and the time of day (4:25 p.m. EST) is a common time for blasting in limestone quarries and coal strip mines. However, this is not an active mineral-producing area of Ohio and the *1995 Report on Ohio Mineral Industries* (Weisgarber, 1996) does not indicate any active limestone quarries within 30 km of the computed location. The closest mineral-extraction operations are two shale pits, each more than 20 km from the computed epicenter. These operations have not used blasting for more than 30 years.

Although this event must be regarded as of suspicious seismic origin, the occurrence of earthquakes in 1998 and 2001 in nearby southern Huron County, which were felt but not immediately reported, and a felt earthquake in this general area in 1927, suggests that this may have been a small earthquake.

February 19, 1995  
Highland County  
lat 39.120°, long -83.470°  
MMI = V  
M = 3.6

The University of Kentucky Seismic Network and U.S. Geological Survey stations recorded this earthquake, in eastern Highland County, south of Marshalltown, and west of Fort Hill State Memorial. The U.S. Geological Survey indicted MMI V at Cynthiana; IV at Hillsboro and Seaman; and III at Cherry Fork, Mowrystown, and Winchester. A report to the ODNR Division of Geological Survey from a citizen living near Bainbridge indicated that his dog “abruptly got up about four seconds before the house began a noticeable shaking that lasted for three or four seconds, followed by five seconds of quiet, the three quick jolts in a second or less.” Wire service press reports note that the earthquake was felt in Belfast and New Market.

February 23, 1995  
Ashtabula County  
lat 41.870°, long -80.800°  
MMI = IV  
M = 2.9

Another earthquake in the Ashtabula sequence was felt in this community and was recorded by the Geological Survey of Canada. The Ohio Seismic

Network relocated the event using Geological Survey of Canada phase-arrival data and the Ohio velocity model. This revised location is on the southwest side of Ashtabula, about 3 km west of the 2001 events. The earthquake awakened many residents of Ashtabula and reported dishes and windows rattled and a booming sound that many thought was a sonic boom. The police department reported numerous phone calls. No damage was reported.

April 9, 1995  
Ashtabula County  
lat 41.970°, long -80.750°  
M = 2.4  
MMI = Not felt

Seismic stations of the Geological Survey of Canada recorded a small earthquake. The present location, which is not well constrained, is beneath Lake Erie, between Ashtabula and Kingsville-on-the-Lake, about 6 km offshore. No felt reports were received for this early morning event.

May 14, 1995  
Lawrence County  
lat 38.710°, long -82.602°  
M = 2.5  
MMI = Not felt

The University of Kentucky Seismic Network recorded a small earthquake in northwestern Lawrence County, in a sparsely populated area of the Wayne National Forest. No felt reports were received for this event. This is the only earthquake recorded from this area. There was no coal strip mining in the vicinity in 1995 (Weisgarber, 1996) and Sunday afternoon is an unlikely time for blasting.

January 27, 1998  
Lake County  
lat 42.030°, long -80.990°  
M = 3.0  
MMI = Not felt

The Geological Survey of Canada recorded this earthquake. The current location of the event is far offshore from an area between Madison-on-the-Lake and Geneva-on-the-Lake. However, this location is very generalized. There were no felt reports for this earthquake.

January 30, 1998  
Lake County  
lat 41.970°, long -81.070°  
M = 2.4  
MMI = Not felt

This small earthquake was recorded and located by the Geological Survey of Canada. The location is beneath the Ohio waters of Lake Erie, offshore from Madison-on-the-Lake. There were no felt reports.

November 25, 1998  
Huron County  
lat 41.020°, long -82.543°  
MMI = IV  
M = 3.2

This earthquake was recorded and located by the Geological Survey of Canada. No felt reports were immediately received by the ODNR Division of Geological Survey. It was not until later that a Division geologist, reading back issues of her hometown newspaper, discovered an article in the November 25, 1998 issue of the *Norwalk Reflector*, titled "Boom puzzles officials," that coincided with the instrumentally detected earthquake. The article noted that houses shook in northern Richland and southern Huron Counties and the Huron County sheriff's office "received between 30 and 40 calls from residents saying they heard an explosion and that their house shook at about 10 p.m." The article reported that people in Shelby, Tiro, Willard, Plymouth, North Fairfield, Greenwich, and Fitchville felt the earthquake.

The instrumental epicenter, which correlates well with the distribution of felt reports, is in southern Huron County, southwest of Greenwich. This specific area had no record of previous seismicity; however, a small event in Richland County in 1927, four small events in Ashland County in 1940, and a small questionable event in western Richland County in 1995 may be related to the more precisely located event in 1998. Another earthquake in this location on July 26, 2001, provides confirmation of seismicity in this area (Hansen, 2001). No damage was reported for this event.

December 25, 1998  
Medina County(?)  
lat 41.120°, long -81.750°  
M = 2.8  
MMI = Not felt

The Geological Survey of Canada recorded this small earthquake in a rural area of eastern Medina County, west of Akron. No felt reports were received. The event was relocated by the Ohio Seismic Network using GSC phase arrivals to lat 41.150°, long -81.460°, which puts it in Summit County. This event is poorly constrained.

## Border Region Earthquakes

This portion of the catalog lists all known earthquakes of 2.0 magnitude or greater that had epicenters outside of State of Ohio borders but within a grid arbitrarily defined as 38.0 degrees north latitude to 43.0 degrees north latitude by 80.0 degrees west longitude to 85.5 degrees west longitude. This grid incorporates most small earthquakes that were near the Ohio border and that may have been felt in the state in these border regions. Some early events in this portion of the catalog, for which little information exists, may have had epicenters in Ohio, or perhaps beyond the border region.

### Events listing

1791 or 1792  
Kentucky

Daniel Drake (1815) noted an earthquake in Ohio's southern border region. His account, the source of which is not specified, is as follows:

*The second shock was in the year 1791 or 1792. I am unable to ascertain the precise time, but think it occurred in the month of April or May, about 7 o'clock in the morning. The weather was fair and mild. The jar was sufficient to agitate the furniture of the house. A rumbling noise in the earth, which seemed to pass from west to east, preceded the shake. It was, I believe, generally felt through the northern and northeastern parts of Kentucky, but whether beyond them I have not been able to learn.*

September 5, 1817  
Kentucky  
lat 38.5°, long -84.5°  
MMI = IV  
M = 3.1

The documented account(s) for this event has not been located for this report.

May 30, 1823  
Ontario  
lat 42.5°, long -81.0°  
MMI = III  
M = 2.7

Dawson (1860) noted this event with the following brief description: "On the shore of Lake

Erie, slight but water of Lake rose to height of 9 feet." There is obviously a great deal of uncertainty as to whether or not it was an earthquake, and Seeber and Armbruster (1993) regarded it as a doubtful event. The nine-foot rise of water level was probably caused by a seiche or a "rogue wave" owing to an intense local meteorological disturbance. Weston Geophysical Corporation's (1979) investigation of this event interpreted it to be an earthquake, near the Canadian shore of Lake Erie. They commented: "Possibly, a sudden rise of water level is normal in May." Such sudden, large rises in water level are not normal at any time of the year and are almost always associated with strong, steady winds blowing across the Lake and piling water on the leeward side or, as noted above, an intense, local meteorological event.

July 15, 1824  
West Virginia  
lat 39.7°, long -80.5°  
MMI = IV  
M = 4.1

*The Evening Post*, New York, July 18, 1824 reported:

*A severe shock of an earthquake was felt on Thursday, 15<sup>th</sup> inst. twenty minutes after 11 o'clock, A.M. in the town of Weston, Lewis county, (W.) Va. and it is said was slightly felt by a few individuals in Clarksburg.*

Another article featured in the *Gettysburg Compiler*, Gettysburg, Pennsylvania, on July 28, 1824 notes the event was also felt in Wheeling, West Virginia. It states:

*A smart shock of an earthquake was felt in this place on Thursday last; it occurred a few minutes before 12 o'clock, and continued an unusual length of time.*

November 20, 1834  
Kentucky  
lat 38.65°, long -83.8°  
MMI = V  
M = 3.5

John G. Armbruster provided the following account, from *The Investigator and Democratic Expositor*, Georgetown, Ohio, November 24, 1834:

A severe shock of an earthquake was felt at this place by a number of our citizens at about half past one o'clock p.m. on last Thursday. The first appearance was that of a loud noise succeeded by a

tremendous shaking. The same was felt at Maysville, Kentucky at about the same hour of the day.

Docekal (1970), citing Collins (1882), stated: "A sharp earthquake in northern Kentucky shook houses 30–40 seconds. Plaster cracked and sounds like distant thunder were reported." Ann Metzger (CERI), in researching this event, could not find any accounts of it in four available Kentucky newspapers. She placed the epicenter near Maysville, Kentucky, as is the approximate location of the highest intensities.

March 8, 1854  
Kentucky  
lat 38.2°, long -85.2°  
MMI = IV  
M = 3.1

The documented account(s) for this event has not been located for this report.

February 27, 1857  
Ontario\Lake Erie  
lat 42.31°, long -80.94°  
MMI = V  
M = 4.1

In earlier catalogs, this event was placed southeast of Ashtabula, Ashtabula County, Ohio. This location was based on newspaper accounts from northeastern Ohio and adjacent areas of Pennsylvania (see following paragraphs). Seeber and Armbruster (1993), on the basis of additional newspaper accounts from Ontario, reevaluated this event and relocated it beneath Canadian waters of Lake Erie, just north of the Ohio/Canadian border. They increased the maximum Modified Mercalli Intensity and greatly expanded the felt area on the basis of these new data. The following newspaper accounts were compiled by Weston Geophysical Corporation (1979).

From *Sentinel*, Ashtabula, Ohio, March 5, 1857:

*Between 8 and 9 o'clock on Friday evening of last week, there was a very sensible trembling of the Earth observed in these parts. The vibration lasted several seconds, jarring houses in such a manner as to alarm the inmates. It was felt in various parts of the county, and is of course the subject of much speculation.*

From *Western Reserve Chronicle*, Warren, Ohio, March 18, 1857:

*An Earthquake—The Conneaut Reporter of the 5th inst, says: The quiet of our citizens was disturbed on Friday evening last, by experiencing a shock of an earthquake at about 20 minutes before 9 o'clock. The shock was so peculiar, so unlike anything before felt, that it attracted very general notice. Buildings trembled and furniture rocked. The shocks lasted about five or six seconds, and passed away with a hollow sound, like distant—very distant thunder... A correspondent of the same paper writing from Jefferson in the same county says: 'Friday night a slight shock of an earthquake was felt by many of our citizens at 8 ½ o'clock—jarring houses, and trembling with considerable force. We are informed that the shock was sensibly felt at Farmington, in this county.'*

*The Conneautville, Pa., Courier says, that a distinct and heavy shock of an earthquake was experienced in that place and various parts of the country around there, on Friday evening 28th ult. Various buildings swayed to and fro perceptably (sic); windows rattled, and the furniture creaked and jarred. The shock was accompanied by a sharp rumbling sound, likened by many to a wagon passing hastily over a bridge. A gentleman from Hayfield says the vibrations caused his clock to keep up a constant striking for ten minutes; another, that the water in his well which was uncovered, at intervals during Friday, bubbled like a boiling kettle.*

From *Painesville Telegraph*, Painesville, Ohio, March 5, 1857:

*On Friday evening last, a few minutes before 9 o'clock, there was felt in this town a smart shock of an Earthquake. How extensively the shock may have been felt we know not. We see no mention of the affair in any of our exchanges. In the neighboring town of Concord, we learn that the swaying was sufficient to crack the walls of a stone house. A correspondent at Unionville makes the following report of the event in that locality: "MR. FRENCH—Last evening about a quarter before nine o'clock, a shock of an earthquake was felt in this place. The rumbling was heard a moment for two before the jarring occurred, --and that was severe enough to give our dwellings considerable*

*shaking. It continued some ten seconds, and seemed entirely different from an ordinary jar. Yours truly, P. Terry, Unionville, Saturday, 28."*

February 20, 1869  
Kentucky  
lat 38.1°, long -84.5°  
MMI = V  
M = 3.4

Docekal (1970) reported: "A shock at Lexington, Kentucky was accompanied with rumbling. Motion was from the southwest. No damage was reported from the city or the countryside."

April 9, 1869  
Ontario  
lat 42.7°, long -80.6°  
MMI = III  
M = 2.9

Smith (1962) noted: "Felt at Vienna, Ontario." Weston Geophysical Corporation (1979) could not find mention in newspapers of it being felt in Ashtabula, Ohio.

February 20, 1876  
Michigan  
lat 41.91°, long -83.48°  
MMI = III  
M = 3.3

This event was reported from Monroe, Michigan. Fujita and Sleep (1991) stated: "The event consisted of a rumbling noise followed by a loud discharge which shook buildings, rattled windows, jarred loose objects, and cracked glasses and lasted 5 s...It was also reported that the event was felt over a radius of several miles and that some rocks had been thrown up in an area 75-100 m<sup>2</sup>." Based on this report, Fujita and Sleep suggest this event was likely a blast or cryoseism.

August 17, 1877,  
Michigan  
lat 42.3°, long -83.3°  
MMI = V  
M = 3.1

Docekal (1970) gave the following account:

*The western part of Detroit was shaken by a slight earthquake lasting 30 seconds to 1 minute. At nearby Greenfield and Redford,*

*Michigan, houses trembled, horses were frightened, and a noise like a train was reported. Livonia, Michigan, also reported the shock.*

Hobbs (1911) said concerning this event:

*On August 17, following, at 11 a.m., a slight shock was felt at Detroit and in a few of the neighboring towns. It lasted from thirty seconds to a minute and was accompanied by a rumbling sound.*

May 23, 1883  
Kentucky  
lat 38.4°, long -82.6°  
MMI = IV  
M = 3.1

*The Bourbon News*, Millersberg, Kentucky, May 25, 1883 and the *Stark County Democrat*, Canton, Ohio, May 26, 1883 each reported earthquake shocks felt at Catlettsburg, Kentucky. Docekal (1970) corroborated: "Two distinct shocks were felt at Catlettsburg, Kentucky."

August 10, 1884  
New York  
lat 40.6°, long -74.0°  
MMI = VII  
M = 5.5

This strong earthquake was felt in Cleveland and portions of northeastern Ohio. Stover and Coffman (1993) summarized the event:

*This severe earthquake affected an area roughly extending along the Atlantic Coast from southern Maine to central Virginia and westward to Cleveland, Ohio. Chimneys were knocked down and walls were cracked in several States, including Connecticut, New Jersey, New York, and Pennsylvania. Many towns from Hartford, Connecticut, to West Chester, Pennsylvania.*

*Property damage was severe at Amityville and Jamaica, New York, where several chimneys were 'overturned' and large cracks formed in walls. Two chimneys were thrown down and bricks were shaken from other chimneys at Stratford (Fairfield County), Conn.; water in the Housatonic River was agitated violently. At Bloomfield, N.J., and Chester, Pa., several chimneys were downed and crockery was broken. Chimneys also were damaged at Mount Vernon, N.Y., and Allentown, Easton,*

and Philadelphia, Pa. Three shocks occurred, the second of which was most violent. This earthquake also was reported felt in Vermont, Virginia, and Washington, D.C. Several slight aftershocks were reported on August 11.

Interestingly, this event was felt by Dr. John Strong Newberry, second State Geologist of Ohio (1869–1882) while sitting in his office at Columbia University in New York City. His astute description of the event was published in the *Columbia School of Mines Quarterly*, October, 1886 (reference courtesy of Steve Madsen via Robert Hook).

Two years ago New York suffered an earthquake shock, but fortunately not a severe one. It occurred about two o'clock Sunday afternoon, the 10th of August. I was sitting alone in my room in the College, where all was perfectly still; suddenly I heard a heavy rumbling sound like that of a passing loaded wagon ten times magnified. At the same time the building began to vibrate, the windows rattled and some light objects were disturbed and fell to the floor. I was sensible of a tremor that not only jarred but swayed my body and caused my book to vibrate and swing in my hand. I recognized the nature of the phenomena at once, observed the time and made a note of it. Subsequently going into the geological cabinet I found palpable evidence of the force of the vibrations. In a case occupied by specimens of marble, many of which were set on edge against the back of the case, all such were thrown down and some were broken. As the back of the case was toward the north, this proved that some of the vibrations were from that direction. This earthquake was noticed by a number of observers, and their testimony showed that the area affected was, as usual, elliptical in outline, and extended from Washington, D.C., to Portsmouth, Me., and from Harrisburg, Pa., to the Atlantic.

March 1, 1886  
Indiana  
lat 39.0°, long -85.5°  
MMI = IV  
M = 3.0

Docekal (1970) stated: "Butlersville, Indiana, reported a distinct shock lasting 10 seconds, with motion coming from the northeast."

Many regions of southwest Ohio, ranging from Columbus to Cincinnati, reported feeling a shock of an earthquake. However, it was later determined this was the result of the Xenia Powder Mill explosion.

*The Hocking Sentinel*, Logan, Ohio, on March 04, 1886 wrote:

There was much talk on the streets Monday last, about a mysterious rumbling sound and shaking of buildings at 10 o'clock in the morning, and it was generally thought that we had felt the shock of an earthquake.

Rumors, late in the evening, disproved this theory and state that there had been a tremendous explosion somewhere.

In the telegraph reports of the daily papers, Tuesday morning, is given a report of a frightful explosion at Miami Powder Co. Works, five miles from Xenia, O. The details of the disaster are sickening...

This was the most terrific explosions (sic) ever experienced at that point. Doors and windows were crushed in and the effects of the shock felt over one hundred miles away.

It is likely that the ground motions reported in Indiana were, in fact, due to this extreme explosion.

June 10, 1886  
Indiana  
lat 39.34°, long -85.48°  
MMI = III  
M = 2.9

The documented account(s) for this event has not been located for this report."

December 15, 1890  
Pennsylvania  
lat 41.41°, long -80.39°  
MMI = II  
M = 2.9

This event was mentioned in the *Pittsburgh Dispatch*, Pittsburgh, Pennsylvania, December 17, 1890. The article states, "Greenville thinks it felt an earthquake shock yesterday."

On December 20, 1890, the *Tyrone Daily Herald*, Tyrone, Pennsylvania, wrote:

About 9 o'clock Thursday night the shock of an exploding meteor was perceptible to residents here. The concussion was preceded by a bright red light, which lit up the northwest sky. Parties residing some three miles northwest

of here say the shock was quite stunning in the vicinity. Two distinct shocks were felt here, the first a very slight one, but was followed a few minutes later by one that shook the houses, many citizens supposing there was an earthquake.

The reports of bright light associated with this event suggests a nonseismic source.

January 11, 1893  
Indiana  
lat 38.28°, long -85.75°  
MMI = IV  
M = 3.8

*The Indianapolis journal*, Indianapolis, Indiana, January 13, 1893 reports:

A severe earthquake shock was thought to have been felt at Jeffersonville at 8 o'clock Wednesday night. The shock rattled the doors and windows, and shook houses. Persons walking on the streets felt the tremor.

November 24, 1894  
West Virginia  
lat 39.27°, long -81.56°  
MMI = IV  
M = 3.8

A blurb in *The Wheeling Daily Intelligencer*, Wheeling, West Virginia, November 24, 1894 stated a slight earthquake shock was felt in Parkersburg, West Virginia. There were no known Ohio felt reports for the event.

August 19, 1895  
Kentucky  
lat 38.53°, long -83.75°  
MMI = III  
M = 3.2

An article in the *Daily Public Leger*, Maysville, Kentucky, August 20, 1895 described this event:

About the noon hour yesterday the majority of the people around this city were startled by a low rumbling sound resembling the noise made by a steamboat in emptying the mud drum, and at the same time by a distinct shaking of the earth.

In some place in the county the windows rattled, dished and glassware made a loud noise, rocking-chairs rocked, clocks stopped

and people were greatly alarmed for the space of several seconds.

The following day, the same publication reported the earthquake was felt distinctly at Washington and a rumbling noise was heard along with a slight shock in Flemingsburg.

June 17, 1897  
Kentucky  
lat 38.05°, long -84.50°  
MMI = II  
M = 2.9

On June 18, 1897, an excerpt from *The Bourbon News*, Paris, Kentucky, stated:

Several reliable persons in this city felt a slight earthquake shock yesterday morning about 12:15. The shock was also felt by parties in Millersburg, Louisville and Owingsville.

March 5, 1902  
Kentucky  
lat 38.14°, long -83.76°  
MMI = IV  
M = 3.8

From *The Bourbon News*, Paris, Kentucky, March 07, 1902, "An earthquake shock was distinctly felt Wednesday morning at Owingsville and lasted several seconds. The vibration appeared from the northwest, going southeast."

There are no indications this event was felt in Ohio.

March 10, 1902  
Indiana  
lat 39.9°, long -85.2°  
MMI = IV  
M = 3.0

Docekal (1970) reported: "Hagerstown, Indiana, felt two distinct shocks."

January 1, 1903  
Indiana  
lat 39.9°, long -85.2°  
MMI = III  
M = 2.7

Docekal (1970) stated: "Two distinct shocks lasting several seconds were felt at Hagerstown,

Indiana. The last shock was more severe.”

October 22, 1909  
Kentucky  
lat 38.9°, long -85.5°  
MMI = II  
M = 2.5

Docekal (1970) stated: “A shock was reported at Scott, Kentucky.”

February 22, 1918  
Michigan  
lat 42.8°, long -84.2°  
MMI = IV  
M = 3.1

Docekal (1970) and Fujita and Sleep (1991) reported the event was felt at Morrice, Michigan. A frost crack 150 feet long and 4 feet deep with numerous diverging cracks was reported, along with ground shaking for 1 sec. There is a possibility that this was a cryoseism (see “Nonseismic earth movements” on p. 53 and not a tectonic event.

September 27, 1921  
Pennsylvania  
lat 42.1°, long -80.2°  
MMI = III  
M = 2.9

Docekal (1970) reported: “Erie, Pennsylvania felt a light shock lasting 45 seconds.”

March 16, 1922,  
Ontario  
lat 43.0°, long -82.5°  
MMI = III  
M = 2.9

Smith (1962) reported: “Felt faintly by a few persons at Port Huron, Mich.”

According to the *Battle Creek Enquirer*, Battle Creek, Michigan, March 16, 1922, several residents in Port Huron, Michigan were awakened by the shaking, but no damages were reported.

August 12, 1929,  
New York  
lat 42.91°, long -78.40°  
M = 5.2  
MMI = Felt

An article in the *Norwalk Reflector* (Ohio) on August 12, 1929, stated:

*Press reports that today's earthquake shocks were not felt further westward than Ashtabula, but facts are that the tremors were plainly felt in Norwalk. A resident of this city states that about 6:15 a.m., his house rocked and was jarred for a time that corresponds with the shaking reported some distance east of here. Windows rattled and it seems certain that the jars were caused by the earthquakes and not by motor trucks or railway trains.*

February 16, 1930  
Ontario  
lat 42.5°, long -80.3°  
MMI = III  
M = 2.9

Smith (1966) described this Canadian earthquake: “Felt in Ontario at Simcoe and Tillsonbur, where it rattled windows and dishes.” There were no reports that it was felt in Ohio.

November 20, 1930  
Michigan  
lat 42.6°, long -83.4°  
MMI = III  
M = 2.9

Smith (1996) reported this event was felt near Oxbow, Union, Green, Cass, Orchard, and Straits lakes. No damage was reported.

There are doubts as to whether this event was an earthquake. Fujita and Sleep (1991) reported:

*The Detroit Free Press reports that the cause was an explosion on Commerce Lake, near Oakley Park, probably of 53 lbs (114 sticks) of dynamite which had been stolen from a gravel pit. The blast was also felt or heard in Birmingham, Pontiac, Drayton Plains, Highland, Milford, and Keego Harbor; a radius of about 25 km.*

May 28, 1933  
Kentucky  
lat 38.6°, long -83.7°  
MMI = V  
M = 3.4

Docekal (1970) reported: “A fairly strong earthquake at Maysville, Kentucky, shook the logs in a log cabin and rattled dishes and windows. At

Ripley, Ohio, a child was said to have been thrown from a swing.”

October 29, 1934  
Pennsylvania  
lat 42.0°, long -80.2°  
MMI = V  
M = 3.2

Docekal (1970) reported: “A strong local shock at Erie, Pennsylvania, knocked dishes from shelves and a woman was thrown from her bed.” Weston Geophysical Corporation (1979) investigated this event and found extensive coverage of it in northeastern Ohio newspapers. Although the earthquake was intense at Erie, Pennsylvania, shaking buildings, knocking dishes from shelves, and breaking a gas line, none of the Ohio newspapers mentioned it being felt in Ohio.

August 26, 1936  
Pennsylvania  
lat 41.4°, long -80.4°  
MMI = III  
M = 2.9

Docekal (1970) reported: “An earthquake felt at Greenville, Pennsylvania, awakened a few persons. The creaking of a house was reported.”

March 13, 1938  
Michigan  
lat 42.4°, long -83.2°  
MMI = IV  
M = 3.1

Docekal (1970) reported: “A local shock jarred western Detroit and portions of Ontario bordering the Detroit River.”

Fujita and Sleep (1991) added the event was felt strongly at Gibraltar, Michigan, Sandwich, Ontario, and Wyandotte, Michigan. Many people in these regions reported an explosive blast due to the noise, but a roaring noise in Gibraltar lasted more than a minute.

August 10, 1947  
Michigan  
lat 41.93°, long -85.00°  
MMI = VI  
M = 4.5

Stover and Coffman (1993) summarized this event:

*Damage was heaviest in the area southeast of Kalamazoo at Athens, Bronson, Coldwater, Colon, Matteson Lake, Sherwood, and Union City. Chimneys were damaged, windows and plaster were broken and brick cornices were downed. Also felt in Indiana, Illinois, Ohio, Wisconsin, and Ontario, Canada.*

June 29, 1957  
Ontario  
lat 42.9°, long -81.3°  
MMI = IV  
M = 3.1

Smith (1959) noted this event as, “About 9 miles south-southeast of London, Ont. Felt at London, Ont.” There are no indications that it was felt in Ohio.

February 9, 1959  
Ontario  
lat 43.0°, long -81.0°  
MMI = IV  
M = 3.1

Smith (1959) described this event:

*East of London, Ont. This shock was not recorded. The epicentre and magnitude were estimated from reports supplied through the courtesy of the London Free Press. The earthquake was felt by a few persons in London and in Charlotteville Township, and by one person on a farm at Walsingham, Norfolk County, all in Ontario.*

There were no reports of this event being felt in Ohio.

September 28, 1966  
West Virginia  
lat 39.3°, long -80.3°  
MMI = IV  
M = 3.1

This event was centered in Harrison County, West Virginia. The *Charleston Gazette*, September 30, 1966, reported, “A mild earth tremor shook an undefined portion of northern West Virginia Wednesday.” There were no reports of damage.

August 11, 1970  
West Virginia  
lat 38.23°, long -82.05°  
MMI = IV  
M = 3.2

This earthquake was centered in Lincoln County, West Virginia. It was instrumentally recorded by the Virginia Tech Seismological Observatory (VTSO) and the NCE. VTSO reported the areas of Charleston, Eskdale, Hamlin, Hurricane, and Saint Albans experienced MMI IV and the earthquake was felt in several regions of west-central West Virginia. There were no indications this event was felt in Ohio.

June 5, 1974  
Kentucky  
lat 38.48°, long -84.75°  
MMI = VI  
M = 3.2

Originating in Owen County, Kentucky, this earthquake was recorded instrumentally by the NCE. No regional report data were collected, so it is unclear whether this event may have been felt in Ohio.

October 20, 1974  
West Virginia  
lat 39.06°, long -81.61°  
MMI = V  
M = 3.8

This earthquake was centered in southern Wood County, West Virginia and was felt in the West Virginia-Ohio border region. The U.S. Geological Survey reported MMI = V at Parkersburg and Ravenswood, WV; MMI = IV at Belleville and New Haven, WV, and Athens, Belpre, Hockingport, and Nelsonville, OH. MMI = III was reported at Cottageville and South Parkersburg, WV and Coolville, Hebardville, Pomeroy, Reedsville, Stockport, and Vincent, OH. An article in the *Athens Messenger* (Ohio), October 21, reported that a chandelier swayed in Athens. This article mentioned that wire service reports at first thought the shock was an explosion. October 20 was a Sunday morning, which would be an unusual time for strip-mine blasting.

February 2, 1976  
Michigan  
lat 41.88°, long -83.73°

MMI = III  
M = 3.4

The U.S. Geological Survey located this event beneath the Canadian waters of Lake Erie, south of Kingsville, Ontario. Seeber and Armbruster (1991) relocated it between Deerfield and Petersburg, Michigan. The USGS PDE (1976) gave the following report:

*Felt sharply in the southern suburbs of Detroit. Felt mildly on the northern shore of Lake Erie from Kingsville to Leamington in Ontario and more strongly on the western shore of Lake Erie including New Boston, Flat Rock, and Grosse Ile, Michigan.*

November 9, 1979  
Kentucky  
lat 38.49°, long -82.81°  
MMI = V  
M = 3.8

This earthquake was felt in parts of Kentucky, Ohio, and West Virginia and had MMI = V in Flatwoods and Rush, Kentucky, where it cracked windows. The U.S. Geological Survey indicated that MMI = IV occurred in Franklin Furnace, Kitts Hill, Haverhill, Lucasville, South Webster, and Wheelersburg, Ohio. It was also felt in Friendship and Ironton, Ohio.

July 27, 1980  
Kentucky  
lat 38.19°, long -83.89°  
MMI = VII  
M = 5.2

This event, centered near Sharpsburg, Bath County, Kentucky, occurred on a Sunday afternoon and generated significant media attention as it was felt by a considerable portion of the population of the region. There was damage to chimneys, cemetery monuments, and other structures in the epicentral area and particularly in Maysville, Kentucky. Ohio communities of Aberdeen, Manchester, and Ripley reported damage to chimneys. A cornice fell from a public building in Cincinnati.

Stover and Coffman (1993) summarized the event:

*This earthquake, the strongest in the history of Kentucky, was felt over all or parts of 15 states and in Ontario, Canada.*

Damage occurred in Indiana, Kentucky, and Ohio.

Property damage was estimated at \$1 million at Maysville, about 50 km north of the epicenter, in Mason County, where 37 commercial structures and 269 private residences were damaged to some extent. Multistory all-brick structures in the downtown area, many of which were built in the mid-1800s, were affected the most. Broken chimneys represented the most common type of damage observed: several toppled or were broken at or near the roofline, some had loosened or broken off their tops, and others sustained cracks of varying lengths and widths. This type of damage was a community-wide effect only in Maysville.

Cracks formed in the ground about 12 km from the epicenter. East of the epicenter, at Owingsville, ground cracks were estimated to be 6 to 10 cm deep and 30 m long. West of the epicenter, near Little Rock, ground cracks extending toward a cistern were observed on Stoner Road.

Detailed intensity/damage surveys were conducted by the U.S. Geological Survey and other institutions, and numerous portable seismographs were deployed in the epicentral area to record aftershocks. Reports on the event were published by Mauk, Christensen, and Henry (1982) and Herrmann, Langston, and Zollweg (1982). The earthquake occurred on a northeast-oriented, right-lateral strike-slip fault that had a small component of thrust, at a depth of about 15 km. The fault ruptured from southwest to northeast, which resulted in a prominent northeast elongation of the felt area. Approximately 60 aftershocks were recorded during a 14-day period following the main shock. The largest aftershock was 2.2 magnitude and was felt.

No previous seismic activity had been recorded in the epicentral area; however, several historic earthquakes placed at Maysville or "northern Kentucky" may have had epicenters in the Bath County area.

August 20, 1980  
Ontario  
lat 41.99°, long -82.99°  
MMI = Not computed  
M = 3.2

Wire service reports indicated that this small earthquake, beneath the Canadian waters of Lake

Erie, just south of Harrow, Ontario, was felt widely in the Detroit, Michigan, area and the Windsor, Ontario, area. There were indications in these articles that it was felt in northwestern Ohio, but no details were provided.

August 25, 1980  
Kentucky  
lat 38.3°, long -83.79°  
MMI = IV  
M = 2.5

The *Louisville Courier-Journal*, August 26, 1980, featured a brief article stating a small earthquake shook Nicholas and Bath counties, but caused no damage in either location.

December 30, 1980  
Kentucky  
lat 38.20°, long -83.91°  
MMI = III  
M = 3.1

This small earthquake, near the epicenter of the July 27, 1980, main shock, was felt at MMI = III at Moorefield and Sharpsburg, Kentucky. Felt reports were noted at Bethel, East Union, Little Rock, Mount Sterling, North Middletown, and Sherburne, Kentucky (Stover, Minsch, Smith, and Baldwin, 1982). This USGS report assigned a magnitude of 1.6 to this event; however, this seems too small considering the felt area. Seeber and Armbruster (1991) assigned the current magnitude of 3.1.

September 5, 1981  
Ontario  
lat 42.80°, long -81.41°  
MMI = Not computed  
M = 3.1

This small earthquake occurred approximately 15 miles (24 km) southwest of London, Ontario. There were no felt reports received by Natural Resources Canada (Allison Bent, written commun., February 9, 2017).

December 23, 1982  
Ontario  
lat 42.77°, long -81.40°  
MMI = Not computed  
M = 2.3

This small event was located almost 17 miles (27 km) southwest of London, Ontario. Natural

Resources Canada received no felt reports (Allison Bent, written commun., February 9, 2017).

November 26, 1982  
Michigan  
lat 42.17°, long -85.48°  
MMI = Not computed  
M = 2.5

Fujita and Sleep (1991) reported:

*On November 26, 1982, a small earthquake occurred near Scotts, about 20 km southeast of Kalamazoo. The event was instrumentally recorded by the stations of the Western Ohio Seismic Array around Wapakoneta, at Allegan County (ACM), and at two stations in central Indiana. The duration magnitude was 2.0-2.5 (Christensen and others, 1987). The event is not reported as being felt and there are no quarries in the area of the event.*

August 17, 1983  
Kentucky  
lat 38.47°, long -82.77°  
MMI = V  
M = 3.5

Stover (1986b) listed intensities for this earthquake centered in Greenup County, Kentucky. MMI = IV occurred in Crown City, Franklin Furnace, and New Boston, Ohio; MMI = III occurred in Ironton, Lucasville, Oak Hill, Portsmouth, Ripley, Rutland, Sciotoville, Scottown, and Wheelersburg, Ohio; MMI = II was recorded in South Webster, Ohio. In addition to northeastern Kentucky, it was felt in parts of West Virginia.

September 3, 1983  
Ontario  
lat 42.75°, long -81.49°  
MMI = Not computed  
M = 2.6

This small earthquake was recorded by the Geological Survey of Canada and located in Elgin County, Ontario. Natural Resources Canada did not receive any felt reports for this event (Allison Bent, written commun., February 9, 2017).

April 14, 1985  
Ontario  
lat 42.95°, long -80.04°

MMI = Not computed  
M = 3.1

This event was located by the Geological Survey of Canada in southeast Hagersville, Ontario. No felt reports were received for this event (Allison Bent, written commun., February 9, 2017).

July 11, 1985  
Ontario  
lat 42.36°, long -80.75°  
MMI = Not computed  
M = 2.6

This event located in the waters of Lake Erie was recorded by the Geological Survey of Canada. No felt reports were indicated.

September 7, 1988  
Kentucky  
lat 38.14°, long -83.88°  
MMI = VI  
M = 4.6

Stover and Coffman (1993) summarized this earthquake:

*An earthquake northeast of Lexington caused slight damage in Bath, Menifee, Montgomery, and Nicholas Counties. Cracks in chimneys and foundations occurred east of Lexington, at Jeffersonville and Means, and northeast of Lexington, at Moorefield. Large cracks formed in exterior walls at Olympia, north of Means, in Bath County. Felt over a large area in several states, including parts of Indiana, Kentucky, Ohio, Tennessee, and West Virginia.*

This event had an epicenter near that of the 1980 Bath County earthquake. The USGS PDE (1988) noted MMI = V at Cherry Fork, Chilo, Felicity, Homersville, Higginsport, Manchester, and Russellville in Ohio. They noted a 3.8-magnitude aftershock two to three minutes after the main shock. Wire service reports indicated that it was felt along the Ohio River from Portsmouth to Cincinnati, and in Springfield, Dayton, and Madison and Pickaway Counties.

July 15, 1989  
Kentucky  
lat 38.61°, long -83.57°  
MMI = V  
M = 3.1

This small earthquake was in Lewis County, Kentucky, just south of Manchester, Ohio. The USGS PDE (1989), reported MMI = V at Vanceburg, Kentucky, and Aberdeen, Manchester, and Ripley, Ohio; MMI = IV at Decatur and Bentonville, Ohio, and Concord, Kentucky; MMI = III at Camp Dix, Carlisle, Dover, Minerva, and Tollesboro, Kentucky, and Cherry Fork and Stout, Ohio.

April 17, 1990  
Indiana  
lat 40.46°, long -84.85°  
MMI = IV  
M = 3.0

This small earthquake was in Indiana, just west of the Ohio-Indiana state line, but appears to have been felt most strongly in Ohio. The USGS PDE (1990a) lists MMI = IV at Burkettsville, Fort Recovery, and St. Henry, Ohio, and MMI = III at Berne, Bryant, Geneva, and Portland, Indiana. Inquiries by the ODNR Division of Geological Survey to the Mercer County, Ohio, sheriff's office, indicated that they received felt reports from Durbin, Fort Recovery, St. Anthony, and St. Henry. Many people thought it was an explosion or a sonic boom.

September 8, 1990  
Kentucky  
lat 38.06°, long -83.73°  
MMI = V  
M = 3.3

The USGS PDE (1990b) indicated that this event had MMI = V at Salt Lick and Stanton, Kentucky, and MMI = III at Flemingsburg, Hillsboro, Jeffersonville, Mount Sterling, Owingsville, Preston, and Sharpsburg, Kentucky. There were no felt reports from Ohio.

December 17, 1990  
Pennsylvania  
lat 41.95°, long -80.12°  
MMI = III  
M = 2.5

This event was recorded and located by the John Carroll University Seismic Network. The USGS PDE (1990c) reported that it was felt (MMI = III) at Erie, Pennsylvania.

June 28, 1991  
West Virginia

lat 38.28°, long -81.67°  
MMI = Not computed  
M = 3.2

The USGS PDE (1991) indicated that this event was felt near Charleston, West Virginia.

August 12, 1992  
Kentucky  
MMI = Felt  
M = 2.8

The University of Kentucky Seismic Network recorded and located this event in Carter County, Kentucky. This network received felt reports from near Greenup, Kentucky.

September 2, 1992  
Kentucky  
MMI = Not felt  
M = 2.3

This small earthquake, in the Bath County area of the July 27, 1980 event, was recorded and located by the University of Kentucky Seismic Network. No felt reports were indicated.

September 14, 1992  
Kentucky  
MMI = Not computed  
M = 2.4

This small earthquake, in Bath County, Kentucky, near the epicenter of the July 27, 1980 event, was recorded and located by the University of Kentucky Seismic Network. No felt reports were indicated.

November 1, 1993  
Ontario  
lat 42.69°, long -81.17°  
MMI = Not computed  
M = 2.8

This event was felt by several citizens in Port Stanley, Ontario (Allison Bent, written commun., February 9, 2017). There were no reports of damage.

July 6, 1994  
Ontario  
lat 42.72°, long -81.51°  
MMI = Not computed  
M = 2.3

This small earthquake was recorded by the Geological Survey of Canada. They located the event in Elgin County, Ontario. No felt reports were received.

September 2, 1994  
Michigan  
lat 42.80°, long -84.60°  
MMI = V  
M = 3.4

Per Faust and others (1997) this earthquake originated southwest of Lansing, at Potterville, and was felt throughout much of central Michigan. The felt area was approximately 6,000 km<sup>2</sup> and ranged from Owosso and Portland to south of Bellevue. The felt reports range from II to V on the MMI scale. Many reports of multiple shocks were obtained.

There are no indications of this event being felt in Ohio.

February 5, 1995  
Ontario  
lat 42.74°, long -81.50°  
MMI = Not computed  
M = 2.4

This small earthquake was recorded by the Geological Survey of Canada. They located the event in Elgin County, Ontario. There were no indications of this earthquake having been felt.

December 30, 1995  
Ontario  
lat 42.85°, long -82.31°  
MMI = Not computed  
M = 2.7

This small earthquake was recorded by the Geological Survey of Canada. They located the event in Lambton County, Ontario. No felt reports were received.

March 14, 1998  
Ontario  
lat 42.13°, long -82.48°  
MMI = Not computed  
M = 2.6

This earthquake was recorded by the Geological Survey of Canada. They located the event in Wheatley, Ontario. No felt reports were received.

September 25, 1998  
Pennsylvania  
lat 41.495°, long -80.388°  
MMI = IV  
M = 5.2

The Pymatuning earthquake was one of the largest events in the Ohio region and—like the July 27, 1980 Bath County, Kentucky, earthquake and the January 31, 1986 Lake County, Ohio, earthquake—was subjected to detailed study including field surveys of damage and intensity and monitoring of aftershocks with portable instruments (Armbruster and others, 1998). The epicenter was near Jamestown, Pennsylvania, east of the southern end of Pymatuning Reservoir, a Lake that straddles the Ohio-Pennsylvania border. Maximum MMI in the epicentral area of Greenville and Jamestown, Pennsylvania, was VI, which resulted in the fall of several old chimneys, broken windows, cracks in exterior cement-block walls, fall of ceiling tiles, items shaken from store shelves, significant changes in water wells, and similar effects. One person was reported injured from being thrown to the ground. Although the event was strongly felt in northeastern Ohio, no significant damage reports were received.

An isoseismal map of the earthquake, prepared by the U.S. Geological Survey, depicts a remarkable northward energy focus—there is a marked attenuation of energy to the south. This map contrasts greatly with the isoseismal map for the 1986 Lake County earthquake, centered about 60 km west of the Pymatuning earthquake. Similar asymmetry of isoseismals was noted for the January 26, 2001, Ashtabula earthquake.

The Pymatuning main shock occurred on a northwest-oriented thrust fault that appears to be part of a general trend of faults in this area that continue into Ohio. Remarkably few aftershocks were recorded. The first one was on October 9 and only a few others were recorded in succeeding weeks. There were few historic earthquakes in this area prior to the 1998 event. Small earthquakes were noted in 1852, 1985, and 1987.

November 5, 1998  
Ontario  
lat 42.27°, long -81.58°  
M = 2.3  
MMI = Not felt

This small earthquake beneath Canadian waters of Lake Erie was detected and located by the Geological Survey of Canada. No felt reports were received.

January 24, 1999  
Ontario  
lat 42.26°, long -82.33°  
MMI = Felt  
M = 2.4

Natural Resources Canada received felt reports for this event from Wheatley, Ontario. Tremors were also felt on January 26 and 27 (Allison Bent, written commun., February 9, 2017).

January 27, 1999  
Ontario  
lat 42.33°, long -82.30°  
MMI = Felt  
M = 2.6

This event was reported felt at Wheatley, Ontario (Allison Bent, written commun., February 9, 2017).

June 3, 1999  
Ontario  
lat 42.28°, long -82.23°  
MMI = Not computed  
M = 2.3

This event was recorded and located by the Geological Survey of Canada. It occurred approximately 8.9 mi (14.3 km) south of Chatham-Kent, Ontario. No felt reports were received by Natural Resources Canada (Allison Bent, written commun., February 9, 2017).

October 30, 1999  
Pennsylvania  
lat 42.06°, long -80.40°  
MMI = Not computed  
M = 2.5

This small earthquake was recorded and located by the Geological Survey of Canada. The event was located in the waters of Lake Erie, 6 mi (9.7 km) east of the Ohio-Pennsylvania state border and 4 mi (6.4 km) north of the Pennsylvania coastline. No felt reports were documented.

October 23, 2001  
Michigan  
lat 42.34°, long -84.76°  
MMI = III  
M = 2.9

This small earthquake in Calhoun County, Michigan, north of Albion, was recorded by the MichSeis and OhioSeis networks, and the Geological Survey of Canada, and located using data from stations in these networks. Residents throughout a small (120 km<sup>2</sup>) area north of Albion and west of Springport reported feeling the earthquake.

## Events of Nonseismic Origin or Doubtful Earthquakes

### *Introduction*

Some events recorded in previous earthquake catalogs have questionable seismic origins or their known accounts provide equivocal information for interpretation of the occurrence. It is probable that some of these events were actually small earthquakes, felt only locally, but were misinterpreted as atmospheric or cultural events. To most people, the nature of small earthquakes—usually a sharp jolt and brief shaking accompanied by a loud boom or rumbling sound—resembles an explosion of cultural origin. The general unfamiliarity that most Ohio citizens have with earthquakes prompts them to interpret these events in a more familiar framework of explosions or, in recent decades, sonic booms from aircraft. With the current wide distribution of seismograph stations throughout the state, it generally is possible to determine quickly if an earthquake or mine blast has occurred. However, throughout most of Ohio history such technology has not been available and most evidence for many of these events is anecdotal, that is, brief newspaper accounts summarizing the observations, and opinions, of a few people. The following paragraphs summarize natural and cultural phenomena that may be misinterpreted as earthquakes or incorrectly ascribed to genuine earthquakes of seismic origin.

An interesting paradox exists regarding reporting seismic events. The ODNR Division of Geological Survey commonly receives inquiries from citizens regarding a possible earthquake. Generally, these individuals felt a vibration or shaking that they thought might be an earthquake. In most cases, where only a single inquiry is received, no evidence of ground movement can be seen at the nearest seismic station and no specific cause can be attributed to the event. It is possible, of course, that a very small earthquake, smaller than the detection threshold of the nearest seismic station, occurred close to a home situated on sediments that tend to amplify ground motion, and the event was felt by this individual. However, it is more likely that the event was cultural or atmospheric in origin.

The paradox is that some genuine earthquakes, even those felt by a number of people throughout tens or even hundreds of square kilometers, are not reported to local, state, or federal emergency, law-enforcement, or scientific agencies. Interesting

examples of this paradox are earthquakes that occurred in southern Huron County in 1998 and 2001. The first earthquake was on November 25, 1998, at about 10:00 p.m. EST. This 3.2-magnitude earthquake was felt in a number of communities in Huron and Richland Counties and was reported to local law-enforcement officials as a possible explosion. An article the next day in the *Norwalk Reflector* indicated that the “boom” puzzled officials as to its origin. The event was recorded on some seismic instruments of the Canadian Seismic Network and thought to be a possible earthquake. Confirmation of this event did not reach state officials until several months after the earthquake. On July 26, 2001, a smaller ( $M = 2.7$ ) earthquake occurred in the same area of Huron County. This event was detected instrumentally by the Ohio Seismic Network (which began operations in 1999) and the Canadian Seismic Network; however, no felt reports were received by state agencies. Calls to local law-enforcement agencies did not result in reports. More than a week after the earthquake, a citizen inquiry to the ODNR Division of Geological Survey established that the event was felt and resulted in subsequent additional felt reports.

Another example was a 2.7-magnitude earthquake beneath Lake Erie, offshore from Painesville. Although this event was recorded instrumentally by the Ohio Seismic Network, and the Canadian Seismic Network, it was not until a newspaper article appeared that any felt reports were received. This event would not have been noted in preinstrumental days. The establishment of the U.S. Geological Survey’s “Did You Feel It” website in 1998 has greatly increased citizen reports of shaking, booming sounds, or other phenomena that may be earthquakes or nonseismic events.

This example points out the fact that some small earthquakes may go unreported and may not be in official catalogs. It is very probable that during the 1800s, and even much of the 1900s, small earthquakes went unreported, or at least officially unrecorded, in Ohio. The ODNR Division of Geological Survey encourages citizens to report possible contemporary earthquakes or call our attention to historic ones that may be discovered in old newspaper accounts.

### *Mining activities and natural explosions*

Extraction of mineral commodities, particularly coal, limestone and dolomite, sandstone, salt, clay, and shale, has been an important industrial activity in Ohio since the early 1800s. As the Industrial Revolution gained momentum during the mid-

1800s, these activities increased to meet the demands of society. Explosives began to be used to fracture rock to aid in its removal or to remove overburden. The development of oil-and-gas deposits in Ohio, beginning during the early 1860s, was accompanied by the use of nitroglycerin to fracture oil-bearing rocks in the well. By the late 1880s, this practice was in widespread use in the Lima field in northwestern Ohio (Wickstrom, 1996). By this time, many Ohioans had a general familiarity with vibrations and sounds associated with blasts related to mining activities or oil-and-gas extraction. Awareness of such activities, including accidental explosions associated with mining or other industrial processes, has commonly promulgated public interpretation of vibrations and explosive sounds as attributable to these cultural phenomena, whereas the event may have actually been a small earthquake.

Modern blasting techniques are sophisticated and designed to maximize the fracturing or removal of rock and to minimize the vibrations to nearby homes and businesses. These blasting activities are closely monitored and regulated and rarely result in damage. Most people living in the immediate vicinity of mining operations are familiar with the occasional mild vibrations or air blasts associated with blasts at these sites. In addition, these blasts are commonly predictable as to time of day and even day of the week. Blasting occurs almost always during normal business hours during weekdays or sometimes on Saturday mornings. Common blasting times are during the lunch hour or before the close of business in the late afternoon. Events that occur at other hours are almost never intentional explosions. Seismographs of the Ohio Seismic Network record these blasts from Ohio and adjacent states on a regular basis.

Subsidence, roof fall, and accidental explosions are other mining-related phenomena that may be mistaken for an earthquake; conversely, a small earthquake may be mistaken for one of these events. However, subsidence in coal mines is usually a slow, rather than instantaneous, process that affects a surface area measured in tens or hundreds of feet (Crowell, 2001). It is doubtful that the slow release of energy associated with typical coal-mine subsidence would be mistaken for an earthquake. Roof fall is a sudden phenomenon in which a portion of the roof of a mine falls into the void created by mining. Although roof falls can be catastrophic for miners in an active mine and the release of energy is sudden, it is likely that they would be felt only in a small surface area. Explosions of methane gas in active underground mines could create surface vibrations that could be

misinterpreted as an earthquake. However, these vibrations would be very local and such an explosion would be quickly reported by local news media. Roof fall or collapse into very large mines, such as underground salt or limestone mines, may generate sufficient energy to create a measurable earthquake (albeit nonseismic) locally. Collapse of the roof of a salt mine at Retsof, New York, on March 12, 1994, created a 3.6-magnitude-equivalent event that was felt in several nearby communities. Such collapses are widely reported.

Although no cases have been documented in Ohio, it is possible that leakage of natural gas from shallow hydrocarbon reservoirs, or decay of organic materials, could accumulate in sufficient concentrations that it could be ignited and cause a blast that would be interpreted as an earthquake.

### *Nonseismic earth movements*

Sudden natural movements of large segments of rock may create local vibrations that may be interpreted to be earthquakes of seismic origin. Perhaps one of the best examples is a major rockfall at Elyria, Ohio, on July 23, 1872. Additional investigation of this event by John G. Armbruster revealed that a large block of Mississippian-age Berea Sandstone fell into the gorge of the Black River. Similar rockfalls, in areas of the state where thick, massive sandstones or limestones form cliffs, may be misinterpreted as seismic events. In general, most landslides are slow-moving events and may take hours, days, or weeks to develop. Rockfalls, on the other hand, are sudden, catastrophic events.

Cryoseisms, commonly known as *frostquakes*, may create phenomena that are misinterpreted as small earthquakes. Cryoseisms are caused when interstitial water in saturated, unconsolidated surface sediments freezes quickly, causing an expansion of the sediment. This may cause vibrations in nearby buildings and even loud, explosive noises. Generally, cryoseisms would occur during cold snaps, usually at night when the lowest daily temperatures occur. They are very local and may cause visible cracks in the ground surface. Sudden differential contraction or expansion of building materials can create loud noises that may be mistaken for an earthquake. Multiple reports of booming sounds in Newark, Ohio, on February 14, 2007, and in western Ohio (particularly Darke County) and eastern Indiana on February 10, 2011, were attributed to cryoseisms.

## *Atmospheric events*

Although most people are very familiar with common meteorological (weather) phenomena, events such as storms, high winds, and thunder sometimes can occur in an unusual context and be mistaken for small earthquakes. In particular, sudden strong gusts of wind not associated with a major storm can cause sudden, unanticipated shaking of a building. Similarly, a lightning bolt, with an accompanying clap of thunder that causes vibrations, can occur in a cloudless sky and be unassociated with a storm.

More equivocal, perhaps, are air blasts (sonic booms) associated with natural or cultural phenomena. These booms, as their name implies, are accompanied by sudden, explosive sounds, followed by rumbling as the shock wave moves away, and they can cause strong vibrations of buildings, leading to objects falling from shelves and broken windows. Natural sonic booms originate from that atmospheric entry of cosmic objects such as meteoroids. Culturally generated sonic booms result from the re-entry of satellites, rocket parts, and other such objects into the atmosphere, where they generate atmospheric phenomena similar to meteoroids. More familiar to many people are sonic booms created by supersonic military aircraft that exceed the speed of sound.

Sonic booms are created when an object such as an aircraft or a meteoroid moves through the denser layers of the atmosphere at a speed greater than the speed of sound (about 700 miles per hour at sea level). As the object moves through the atmosphere, the air cannot move out of the way quickly enough and a pressure wave builds up and trails behind the object like the wake of a ship passing through water. When the pressure wave contacts the ground, it creates the loud boom and shaking that characterize these events. The pressure wave follows the object and may have a long, somewhat narrow path.

Artificial sonic booms created by aircraft were common in many areas of the country, including Ohio, during the 1950s when there was considerable experimentation with supersonic aircraft and more civil tolerance of the sudden booms. As more damage claims were filed and more complaints raised, the practice of supersonic flight over populated areas was discontinued. However, there are still infrequent cases where it is probable that a military aircraft briefly exceeded the sound barrier. It is possible that some of these occurrences could have been interpreted as earthquakes. Potentially confusing reports would

not be earlier than the late 1940s and more probably during the 1950s. Sonic booms created by re-entry of satellites and associated artificial debris are uncommon. Sonic booms create signals that can be detected by sensitive seismometers that are favorably placed.

Natural sonic booms, generated by atmospheric entry of meteoroids, are uncommon in any particular area, but they certainly occur across Earth's surface on a regular basis. Larger meteoroids enter the atmosphere at velocities of between 10 and 26 miles per second and become luminous at altitudes of 60 to 90 miles (Norton, 1994). This luminous phase, which is caused by burning of the meteoroid material from frictional drag and ionization of the atmosphere around the meteoroid, may be visible over an area of hundreds of miles. At an altitude of about 10 miles, smaller meteoroids lose their cosmic velocity (point of retardation) and luminescence and fall at gravitational velocity. It is at this point that the meteoroid may explode, accompanied by explosive sounds, and make whistling or whirling sounds as the mass descends. Sonic booms may be associated with the near-end point of the meteoroids' atmospheric entry. Because sound waves travel much more slowly than do light waves, the sonic booms may occur up to a few minutes after the fireball has passed.

It is very possible that sonic booms associated with atmospheric entry of a meteoroid may be mistaken for earthquakes. In a few instances, newspapers have reported the passage of a fireball and an earthquake in the same article with the implication that the two events were similar in time and causally related. The presumed earthquake on September 10, 1886, near Doylestown in Wayne County, is an example. Seldom do such articles reveal if the two events were nearly simultaneous or separated by a sufficient length of time to determine that they were coincidental.

More recent theories suggest that rare but natural electrical events, similar to ball lightning, may cause explosive discharges capable of creating significant air blasts, damage, and small craters. These enigmatic events are mistaken for impacts of energy from cosmic bodies, earthquakes, or more esoteric interpretations such as crash sites of alien spacecraft.

## Events listing

1845  
Putnam County  
lat 41.1°, long -84.2°  
MMI = II  
M = 2.5

Bradly and Bennett (1965), citing an article in the *Columbus Evening Dispatch*, stated: "Earth slump or some type of displacement occurred on a farm in Putnam County. Ridge of ground was shifted approximately four feet. No report of any shock being felt."

The seismic origin of this event is highly doubtful, based on this single report. It is more likely that this may have been a slump along a stream bank or a similar nonseismic event.

February 25, 1866  
Cuyahoga County  
lat 41.5°, long -81.6°  
MMI = ?  
M = ?

Contemporary meteorologists interpreted this disturbance to be a cryoseism (frostquake). However, a small earthquake cannot be dismissed as this area east of Cleveland has experienced a number of small earthquakes, particularly in the near-shore area of Lake Erie. The observation of fissures in the ground suggests a frostquake as these features do not occur with small earthquakes in the region but have been commonly associated with frostquakes. The *Cleveland Daily Leader* on February 26 (reprinted in the *Brooklyn Eagle*, February 27, 1866, p. 4) printed the following account:

*Many of our readers, no doubt, thought our account of the earthquake at East Cleveland yesterday morning a hoax. Whether it was an earthquake, in the general acceptance of that term, or not, the statement that the earth was shaken, accompanied by a loud dull report, and a deep and wide fissure formed, was true. But it is the opinion of our best meteorologists that it was an effect of the extreme cold. The fissure extended for a long distance, North and South, across the Euclid road, running immediately through the houses of Mr. Abner McIlrath, and one or two other residents in that*

locality; the walls of some of which were badly cracked.

*When first examined in the morning, the fissure at the top was said to have been two or three inches wide, and extending into the ground to the depth of several feet. It gradually came together during the day, and is now very nearly closed up.*

*The noise made by this convulsion was heard for quite a distance on each side of the fissure, and was so loud that many were aroused out of a sound sleep by it. Several persons in this city have informed us that they were awakened by the concussion, and all describe it as sounding as though some heavy weight had been dropped near them. The same phenomena were noticed on the west side of the river, and small fissures were seen in the ground in all parts of this city.*

July 23, 1872  
Lorain County  
lat 41.6°, long -82.1°  
MMI = III  
M = Not Computed

Bradley and Bennett (1965), citing articles in the *Columbus Dispatch* and *Cleveland Plain Dealer*, listed this event as an earthquake. They stated: "Felt around Elyria and Lorraine (sic). Felt over several counties. Was either the result or cause of a rockslide." Docekal (1970) repeated the account of Bradley and Bennett.

Weston Geophysical Corporation (1979) investigated this event and concluded, on the basis of original newspaper accounts, that this was a large rockfall. The East Branch of the Black River cuts through a thick section of Berea Sandstone (Mississippian) at Elyria. This sandstone was formerly quarried at Elyria (Newberry, 1874) and forms steep banks and a waterfall at this town. The newspaper accounts mention the Red Mill as near the site of the rockfall. The accounts from the Elyria and Lorain newspapers make no mention of the rockfall being felt "over several counties." There is no doubt that this was a nonseismic event.

From *Elyria Independent*, July 24, 1872:

*This (Tuesday) morning, at a few minutes before six o'clock, the citizens of Elyria were startled by the jarring of the earth, followed by a crashing dull sound, like that produced by the fall of a heavy body. Those living in the vicinity of the Red Mill soon discovered the*

cause. The immense overhanging rock over which the road bed formerly passed to the lower mill, had fallen into the chasm below, with a crash that at once revealed the cause of the alarm.

The rock that fell intact is about one hundred feet long by thirty feet in width and depth and weighs about 4,600 tons. The whole weight of rock that fell, including the detached portions, must have been 7,000 tons. A crevice is opened in the rock, extending around under the corner of the mill to the verge of the falls and there is danger of another fall of rock, which however will not endanger the mill property.

Hundreds of our citizens visited the scene, and looked with wonder upon the change that had been wrought in a moment, by the rending asunder of what has always been regarded as a rock that could only be moved by the force of the most powerful explosive agencies. Sight-seers will do well to avoid the precipice immediately adjoining the part that fell, as the large crevice in the earth shows that it is liable to fall at any moment. The mill stands far enough back to be out of all danger.

March 31, 1884  
Butler County  
lat 39.5°, long -84.7°  
MMI = II  
M = 2.5

Docekal (1970) reported: "Three very light shocks at College Hill, Ohio were noticed by few people and were not generally felt." His sources were the *Monthly Weather Review* for 1884, unpublished notebooks of H. F. Reid, and Rockwood (1885). This event requires additional research for confirmation as an earthquake.

August 15, 1885

(questionable event)

This event is poorly known. An evaluation by Weston Geophysical Corporation (1979) could not find mention of the event in eleven regional newspapers.

From *Monthly Weather Review*, August 1885, United States Weather Bureau, Washington, D.C.: "Garrettsville, Portage County, Ohio: a severe shock, which is supposed to have been due to an earthquake, was experienced at 11:05 p.m. on the 14th."

April 9, 1900  
Cuyahoga County  
lat 41.37°, long -81.85°  
MMI = VI  
M = Not Computed

Docekal (1970) citing articles on April 10 in the *Cleveland Herald* and *Cleveland Leader*, listed this event as an earthquake in which two chimneys on one house fell. Weston Geophysical Corporation (1979) correctly determined that this event was a quarry blast from nearby quarries in the Berea Sandstone, and therefore not an earthquake of seismic origin.

*The Berea Advertiser*, April 13, 1900, portrayed the correct analysis of the event.

Since Berea is a quarry town a blast, a gunpowder explosion, or a miniature earthquake is not all together a novelty. During the quarry season these blasts may be heard at all hours of the day in different parts of the town where ever the quarries are located. Citizens have been startled not only these blasts but also of falling rock as well, which are sometimes thrown to great distances unless proper precautions are taken. The quarry people have become somewhat adept in the use of gunpowder to loosen the rock and in late years very little has been heard of accidents or violent explosions.

Monday morning however, about 8 o'clock a blast occurred which startled the whole village and in some localities it had the effect of a miniature earthquake. Buildings were shaken and 2 chimneys from Dr. Clarks Bridge Street residence were shaken to the ground. The effects was not entirely upon the surface but must have extended to a great depth as shown by the water in several deep wells in the vicinity.

The Cleveland newspapers detailed the effects of the shaking but made no mention of blasting at the quarries. This event is therefore cataloged as a cultural event of nonseismic origin.

June 14, 1902  
Tuscarawas County  
lat 40.35°, long -81.45°  
MMI = IV-V  
M = Not Computed

This event, at 06:00 UTC, was listed by Docekal (1970) based on the unpublished files of H. F. Reid at the U.S. Coast and Geodetic Survey. Docekal described the event as “Newport, Ohio experienced an earthquake. No details.”

There are four towns named Newport in Ohio: Madison County, Shelby County, Tuscarawas County, and Washington County. Docekal (1970) gives the coordinates for this event as near the town of Newport in Tuscarawas County. Whether or not the original report in the H. F. Reid file specifies the community in Tuscarawas County or if these coordinates were added by Docekal based on a map search of towns with this name is unknown. A search of the *Marietta Times* did not produce any articles referring to an earthquake on or about June 14; therefore, Newport in Washington County can be reasonably eliminated from the list. Additional research is needed on this event.

July 9, 1904,  
Erie County  
lat/long unknown  
MMI = Not  
Computed  
M = Not Computed

Although this event is not in earthquake catalogs as a possible earthquake, it is worth describing this significant explosion as such occurrences are commonly mistaken for earthquakes. The *Norwalk Reflector*, October 13, 2000, described a large explosion of a powder magazine on the evening of July 9, 1904, near Marblehead, Erie County, the site of long-time quarrying of the Columbus Limestone.

*A bolt of lightning struck the magazine at the quarry, setting off an explosion or series of explosions from the 10 tons of dynamite and 5,000 pounds of powder stored in the magazine.*

*The shock of the explosion resembled an earthquake, and scores of Marblehead residents fell unconscious from the shock. It was estimated that 100 people were injured to some degree.*

*All of the telephone and telegraph wires were burned out, and the great confusion among the people made it difficult to learn details for some time afterward. Lakeside, not far away, had many windows broken in cottages as well as the hotel and auditorium. The shock of this blast was felt in many*

*northern Ohio towns including Norwalk, and was noted as far away as Cleveland.*

April 23, 1906  
Hardin County  
lat 40.7°, long -83.6°  
MMI = V  
M = 3.4

Docekal (1970), citing the unpublished notes of H. F. Reid (U.S. Coast and Geodetic Survey) stated: “An earthquake was felt at Grants Pass, Ohio” (now Grant, Hardin County). This event is not mentioned in any other list or catalog based on original information, and therefore it is questionable until additional research can be done.

June 22, 1906  
Cuyahoga County  
lat 41.37°, long -81.87°  
MMI = I-II  
M = Not Computed

Weston Geophysical Corporation (1979) discovered a newspaper account of an event felt by one person and regarded as dubious. The instrumental recordings at St. Ignatius College (John Carroll University) cannot be considered proof of an event because the instruments were primitive and not well-suited for recording small, local events.

From *Berea Enterprise*, June 29, 1906:

*Mr. E. M. Carrol felt the vibrations of Mother Earth on the night of June 22nd. The papers did not record the shock, and Mr. Carrol to satisfy himself wrote to the meteorological observatory, St. Ignatius College, Cleveland to know if it had been indicated there. He received the following notice, June 25th, our instruments recorded extensive vibrations on the night of June 22, 23, from 11 p.m. to 2 a.m. They were from the E.W; and were many, turning up in periods of about three minute duration and about that long apart.*

June 27, 1906  
Cuyahoga County  
lat 41.4°, long -81.6°  
MMI = IV-V  
M = Not Computed

Bradley and Bennett (1965) summarized this event: “Felt over a 400 sq. mi. area. Most intense at

Fairport and Put-in-Bay. Doors slammed and windows rattled. Two shocks felt along southern shore of Lake Erie for about 100 mi." It was listed in Heck (1947) and Docekal (1970). Research by Weston Geophysical Corporation (1979) suggests that this was a 20-ton blast at Monroe, Michigan. Extensive coverage of the event by newspapers in lakeshore communities is mostly repetitive. Some of the salient commentary is presented below. There is some controversy that the time of the blast at Monroe, and the time of the intense shaking at various cities, sufficiently differs that two events could be considered. Weston Geophysical pointed out that, although the event was strongly felt for 200 km along the lake shore, from Monroe, Michigan to Painesville, Ohio, felt reports came primarily from communities relatively near the southern shore of Lake Erie. Reports from communities farther inland seem to be lacking. They interpreted this evidence to suggest an air blast rather than a seismic event.

From *Cleveland Leader*, June 28, 1906:

*A violent earthquake shock shook the southern shore line of Lake Erie for a distance of one hundred miles yesterday afternoon, the eastern limit being Painesville and the western Marblehead.*

*It was learned last night that there was a severe powder explosion near Detroit. For a time this gave rise to the theory that it might account for the disturbances on this side of the Lake, but a comparison of the time seemed to make this impossible. According to seismographic registration the shock occurred at 4:10 o'clock, while the explosion was at 4:40. Even the average time of 4:20 o'clock set by the general public as when the shock was felt, would leave twenty minutes to be accounted for.*

From *Elyria Reporter*, June 29, 1906:

*The supposed earthquake shocks felt here and in other places turns out to be the effect of a dynamite explosion. A dispatch from Monroe, Mich., says that the shock was felt there, and was caused by the explosion of twenty tons of dynamite stored in a scow at the mouth of the Detroit River. The dynamite was the property of contractors engaged in deepening the channel at the Limekiln crossing near Amherstburg, Ont. and was exploded by some sailors on a yacht shooting into the scow. Many windows for miles around*

*were broken, and the foundations of several buildings were cracked.*

April 12, 1907

Cuyahoga County

lat 41.5°, long -81.7°

MMI = Not Computed

M = Not Computed

Docekal (1970) listed this event based on the unpublished notes of H. F. Reid at the U.S. Coast and Geodetic Survey. He said, "a local shock lasting 1 minute on the St. Ignatius College seismograph was reported at Cleveland, Ohio." Weston Geophysical Corporation (1979) reviewed Reid's notes and interpreted his hand-written comments to clearly indicate that this was not an earthquake and the seismograph was not performing well on that day.

1914

Shelby County

lat 40.4°, long -84.2°

MMI = III

M = 2.9

Rouse and Priddy (1938) mentioned this event in a list of Anna-area earthquakes as "?—1914--slight." They did not cite their source and considered it a questionable event.

September 9, 1928

Lorain County

lat 41.5°, long -82.0°

MMI = V

M = Not Computed

This event was evaluated by Weston Geophysical Corporation (1979), from local newspaper accounts. They regarded it to be of uncertain origin and stated:

*The location, intensity, and nature of the seismic activity observed on this day all remain somewhat mysterious. Three distinct tremors were observed over a rather large area along the Lake from East Cleveland to Port Clinton. Some of the felt reports can be evaluated in the IV–V intensity range, but it is never clear how the intensities of the three events compared with each other.*

*One source of confusion arises from the fact that a bombing exercise took place just about the same time (3:00 p.m. local time) at Camp Perry (7 miles from Port Clinton). Some*

reports, e.g. "distant thunder," "earthquake appeared remote," "three distinct rumblings," could be interpreted in support of the theory that the bombing exercise was indeed the cause of the felt reports. But this interpretation was not accepted in United States Earthquakes (Heck and Bodle, 1930): "It is not thought that the tremors were a result of these operations." Unfortunately, the reasons for this rejection are not given. One disturbing question comes from the fact that the seismograph at John Carroll did not record any earthquake signals that afternoon. This is hard to reconcile with the true occurrence of a seismic event (Intensity V) located near Lorain and West Cleveland. The absence of a signal on the seismograph could indicate that the observed noise and vibrations were not related to seismic waves, but simply noise (air waves) generated by bombs exploding with a poor coupling to the ground.

This event remains enigmatic. Newspaper reports indicate that at Port Clinton, the "tremors came simultaneously with the explosion of the practice bombs."

June 10, 1929  
Cuyahoga County  
lat 41.5°, long -81.7°  
MMI = Not Computed  
M = Not Computed

Bradley and Bennett (1965), referencing an article in the *Cleveland Press*, said: "Buildings in suburbs in east side of Cleveland shaken. Possibly due to an explosion." This event requires further research.

June 10, 1931  
Henry County  
lat 41.3°, long -84.0°  
MMI = V  
M = 2.8

This event is included in the catalog as a probable seismic event, although, as the following newspaper accounts portray, there was much speculation that the noise and shaking were caused by an explosion of nitroglycerin or by a meteorite impact. A large hole beside the road near Malinta, Henry County, near which there was a large tree and a telephone pole downed, was speculated to be associated with the sound and vibration. The

prevailing contemporary theory seemed to be that the hole was a crater made by a meteorite. There were no reports of bolides (fireballs) in the sky that night in northern Ohio, although an article in the *New York Times* on June 11 (courtesy of Andrei Ol'khovatov), on the Malinta event, indicated that fireballs were seen in the sky on the evening of June 10 in Syracuse, New York, at 8:14 p.m. and in Utica, New York, at 9:30 p.m. These fireballs differ so much in time from the occurrence of the Malinta shock at 1:30 a.m. that there could be no direct connection. Small-magnitude earthquakes in Ohio are commonly accompanied by a loud, booming sound that many people mistake for an explosion. Commonly, rumbling sounds, similar to rolling thunder, follow the initial boom. Of course, sonic booms accompanying fireballs can create similar auditory phenomena.

Bolides are greatly misinterpreted by the public as to their size, velocity, distance, and probable landing area. The luminous phase of a bolide may be visible over a multistate region. In an area in which a meteoroid lands, if it survives atmospheric passage, the fireball appears to burn out directly overhead as atmospheric drag slows it sufficiently so that it is no longer luminous. At this point, sonic booms commonly are heard. It is uncommon for small meteorites to excavate large craters (the Malinta crater was described as 10 feet in diameter and nearly as deep) because atmospheric drag has caused them to lose cosmic velocity and they make their final descent at gravitational velocity. However, sonic booms can be heard over large geographic areas and vibrations from these phenomena can rattle windows and such, leading to misinterpretation of them as seismic events.

There may be no correlation between the hole in the ground and the shaking reported by residents. Indeed, these may be mutually exclusive events. Until additional, contradictory evidence emerges, this event is considered to be of questionable origin.

From *The Tiffin Daily Advertiser*, Tiffin, Ohio, June 10, 1931:

*Malinta, O., June 10 – An earthquake or explosion which early today shook all northwestern Ohio this afternoon became a complete mystery. After digging for several hours into a deep hole near here, a crew of workmen report that they had failed to find any trace of a meteor which at first was believed to have caused the disturbance.*

*An earth tremblor, believed to have been caused by the fall of a huge meteor, shook*

Tiffin and all of northwestern Ohio early today. Scores of persons awakened in fright during the rumble which lasted only a few moments. No damage was reported in this section. The earthquake is believed to have been caused by the fall of a meteor at Malinta, near Napoleon. Although no trace of the meteor could be found, a hole large enough for an automobile was found on the edge of the village.

An additional evidence of the probable fall of a meteor, a large elm tree on the bank of a ditch where the large earth cavity was found, was torn out by the roots and hurled to a point 150 feet away. For several yards on all sides of the holes the ground was splattered with earth which had been blasted away. Grass nearby was burned. Small rocks apparently in the path of the meteor were thrown about. A telephone pole was knocked down and wires for several yards were lowered to the ground.

Persons who examined the hole said that the meteor was evidently embedded deep in the earth. Nobody in the village, it was said, reported seeing any blazing body falling through the sky.

Noise of the crash awakened the entire countryside. The earth shook and at first it was believed that a huge dynamite charge had been set off somewhere in the vicinity. Although the disturbance was most severe here, cities throughout this section were shaken about the time the meteor was believed to have fallen.

Reports of the 'explosion' were received from Findlay, Tiffin, Fostoria, Bluffton, Kenton, Continental and Columbus Grove. Findlay police said the 'blast' sounded like the explosion of a nitroglycerine magazine. People were roused from sleep in all of these places as a result of the temblor. Windows were reported broken in several localities.

From *The Advertiser-Tribune*, Tiffin, Ohio, June 10, 1931:

A tremendous blast, which occurred near Malinta, Henry County and which rocked homes within a 40 mile radius of the village is believed to have been felt slightly here about 1:30 a.m. today.

Mystery surrounding the origin of the shock today and Henry County authorities were investigating to determine whether to attribute

the concussion to the fall of a giant meteor or to the accidental explosion of a quantity of nitroglycerine.

The blast rocked buildings and roused sleepers early today in an area of many miles. Findlay, Fostoria, Bluffton, Continental, Wauseon, Columbus Grove, Napoleon and other villages reported feeling pronounced shocks and earth tremors. In many sections the shock was believed to be a small earthquake.

Police here were questioned by telephone operators who were in the belief that the shock centered around Archbold. Tiffin patrolmen reported hearing an explosion or shock at about the time of the Malinta blast but attributed it to the setting of a blast in the Maple Grove quarries. It is now believed that the Malinta blast may have been heard here.

The explosion or meteor, as the case may be, opened a crater 10 feet in diameter and almost as many feet deep in a ditch along state route 100 (109) near the farm of Henry Pulman about a half mile from Malinta.

Henry County authorities were inclined today to credit the possibilities of an explosion as there is no evidence at the scene but a large hole in the earth. The possibility that nitroglycerine carried in an auto might have caused the blast is doubted since a search of the surrounding territory revealed no trace of wreckage of an auto.

Henry County authorities, incidentally, question whether it was a meteor, leaning to the possibilities of an explosion as there is no evidence at the scene but a large hole in the earth.

However, the manner in which the earth was torn up was held by some to be evidence of a meteor and plans for excavating are being considered. No one saw the meteor, the first evidence of something out of the ordinary being a report accompanied by something of a quake that aroused hundreds of residents in this section. The gaping crater in the earth was discovered later at the side of the road with loose earth at the bottom.

May 31, 1940

Summit County

lat 41.1°, long -81.5°

MMI = II

M = 2.5

Bradley and Bennett (1965) repeated a brief account in *United States Earthquakes, 1940* (Neumann, 1942): "Slight tremor felt by a few people in the vicinity of Akron." Investigation of the event by Weston Geophysical Corporation (1979) found no mention of the event in the *Akron Beacon Journal*. This event is questionable.

December 7 and December 21, 1951  
Cuyahoga & Lake Counties  
lat 41.6°, long -81.4°  
MMI = Not Computed  
M = Not Computed

Bradley and Bennett (1965) note shocks at Willoughby on December 7 and 21 were recorded on the seismograph at John Carroll University. Weston Geophysical Corporation examined these seismograms and "failed to confirm the occurrence of any local event that could be interpreted as a Willoughby tremor." Nor could Weston Geophysical find mention of them in local newspapers. These events were supposedly in the same area as an earthquake on December 3, 1951. Although no seismic record was noted on the John Carroll University instruments, a number of small earthquakes beneath Lake Erie, offshore from the Willoughby area, have been recorded by the Ohio Seismic Network and the Geological Survey of Canada since 2000. Modern broadband sensors have a lower detection threshold than those in use in 1951 and the possibility remains that these events may have been small earthquakes.

May 1, 1958  
Cuyahoga County  
lat 41.49°, long -81.82°  
MMI = IV  
M = Not Computed

This event is listed in many earthquake catalogs, including Bradley and Bennett (1965) and Docekal (1970) and was covered extensively in contemporary newspapers in the Cleveland area. Weston Geophysical Corporation (1979) investigated the event and noted several discrepancies. They interpreted it to be a possible sonic boom generated by military aircraft. It is sometimes very difficult to determine if such events are natural earthquakes or culturally generated sonic booms. Small earthquakes in this area frequently are accompanied by a sharp, loud booming sound that many people interpret as a sonic boom or an explosion. There is seldom confirmation from military authorities that aircraft

were operating in the area at the time of the event and that they were engaged in supersonic flight.

Weston Geophysical Corporation (1979) summarized the evidence:

*The problems arise from the fact that on that evening, John Carroll's seismographs recorded some kind of an event at '6:46 p.m.' according to Dr. E. Walter, station seismologist, and that half an hour later, around '7:15 p.m., numerous felt reports of explosive noises,' mostly on the lake shore, from Lorain to Lakewood were received. Dr. E. Walter confronted with two phenomena, was explicit in his press releases to say that the 7:15 p.m. blast was unrelated to his 6:46 p.m. recorded signal. The newspaper accounts collected recently indicate that the reported noises, shaking, etc. were all associated with the 7:15 p.m. event, and not with the earlier one. Somehow, these reports appear to have been used by government agencies as the basis for assigning an Intensity V (MMI) to the earlier event listed in the USGS catalogs at 16:46. Besides this apparent miscorrelation, the intensity appears overestimated. The collected reports would substantiate an Intensity IV (MM), not V. 'Rattling, shaking, noises, but no damage' does not support more than an Intensity IV. It has already been noted that a large number of telephone calls are often placed out of curiosity; they are not necessarily to be interpreted as a sign of fright.*

*The seismic nature of the 6:46 p.m. event is uncertain. The John Carroll seismograms have been reexamined by two seismologists, Rev. D. Linehan, S.J. and Dr. G. Leblanc. They concluded that it remains dubious that the 6:46 p.m. (local time) recordings were truly indicative of a local earthquake. Only one horizontal component shows good motion and the three or four oscillations of the surface waves have a period much longer (1.5 sec) than what was recorded during the true local events of 1951 and 1955.*

*It is worth mentioning that the local press suggests jet activity (breaking the sound barrier) as possible source for the noises. A careful reading of the press accounts indicate that this theory was dismissed on the basis that a spokesman at Cleveland Hopkins Airport said 'there was no activity in the area all evening.' It is possible that such a statement was not well substantiated; military planes*

have their own independent flight plans. Another remark included in a press account to the effect that 'jets have been active in the area for the past week' would give support to the theory of the noises being related to planes breaking the sound barrier. Dr. Walter, recently consulted on this problem, seems to agree with this hypothesis.

In summary, if this event is conservatively retained as truly seismic, it should be located near Lakewood, with a revised Intensity IV. In doing so, one has to reject the theory of two separate events, and postulate that the 7:15 p.m. felt reports, although originating about a half hour later, were truly related to the recorded event of 6:45 p.m. The observers who attempted to give the time of the noises could have been in error.

March 9, 1977  
Wyandot County  
lat 40.96°, long -83.50°  
MMI = V  
M = Not Computed

The U.S. Geological Survey (Simon, Stover, and Reager, 1979) listed this event as a blast and commented: "Explosives totaling 22.6 metric tons were detonated near Caro (sic = Carey), 88 km south of Toledo. The data were provided by F. Mauk, University of Michigan, Ann Arbor." The data indicated MMI = V at Southfield, Michigan (all awakened and frightened), and MMI = IV at Farmington Hills, Oak Park, and Selfridge Air Force Base (windows and doors rattled over wide area). Michael Mann of ODNR Division of Mineral Resources provided details of this event. This was an explosion of 47,000 pounds of explosives—purposely detonated by a striking employee—in a magazine and semi trailer at a limestone quarry near Carey. The blast created a crater about 100 feet wide and 15–20 feet deep, knocked down a barn, and caused other damage in the area.

Felt reports listed by the USGS seem spurious, as these locations in Michigan are more than 200 km from the blast site. This issue needs further investigation.

September 21, 1986  
Lake County  
lat/long unknown  
MMI = Not Computed  
M = Not Computed

Wire service reports (*Columbus Dispatch*, September 25, 1986) indicated that residents east of Cleveland heard a rumbling noise that shook some homes. Fr. William R. Ott, of John Carroll University seismic network in Cleveland, said that "a very small wiggle in the line" indicated slight seismic activity at

5:16 a.m. EST (09:16 UTC). Fr. Ott added, "I'm a little suspicious that it may simply have been thunder, but I wouldn't rule out a small-intensity earthquake." Gabriel LeBlanc, seismological consultant to Cleveland Electric Illuminating Company, indicated that none of its 10 seismometers in the Lake County area recorded any seismic activity, and he indicated certainty that there was not an earthquake. The National Weather Service indicated that thunderstorms did not reach Lake County until 6:15 a.m. EST.

In the absence of strong data supporting a seismic origin for this shock, it is perhaps most reasonable to assume that it was a meteorological event related to thunderstorm activity. It is very probable that residents of the area were still very sensitive to the occurrence of earthquakes because of the 5.0-magnitude event in Lake County on January 31, 1986.

May 28, 1988  
Noble County  
lat 39.75°, long -81.61°  
M = 3.4  
MMI = Not computed

A large blast in a Central Ohio Coal Company strip mine, in Section 24, Brookfield Township, Noble County, was initially reported by the USGS to be a small earthquake, which resulted in wire service reports (*Columbus Dispatch*, May 29, 1988) in newspapers across Ohio. Further investigation of the event by ODNR Division of Geological Survey failed to find any felt reports in the epicentral area nor confirmation by company officials that they had a large shot at the time of the presumed earthquake. The event was recorded on seismographs as far away as St. Louis, Missouri.

November 29, 1990  
Fairfield County  
lat 39.61°, long -82.83°  
MMI = IV  
M = 2.0(?)

This enigmatic event may have been a small earthquake felt only locally in a rural area. Lack of

nearby seismic stations precludes confirmation or precise location of the event. According to a report in the *Columbus Dispatch*, November 30, 1990, residents of Stoutsville, a village of 350 people in southwestern Fairfield County, felt houses shake at about 10:05 a.m. EST (15:05 UTC). A resident of a modular home reported that the floor shook and pictures fell off the wall, damaging five pictures, collapsing a shelf of knick-knacks, breaking a window, and cracking the house foundation. The resident described a noise “like the rumble of a bowling alley like when you roll the ball down the lane, though it was more of a vibration.” Another resident reported it sounded like a sonic boom. A spokesperson for Rickenbacker Air National Guard Base in Groveport said, “We didn’t have any aircraft down in that area at that time.”

Inquiries by the ODNR Division of Geological Survey to the University of Kentucky Seismic Network and the Anna Seismic Network operated by the University of Michigan revealed no seismic events on their station records at that time. Fr. William Ott, director of John Carroll University (JCU) Seismic Network, was quoted in the aforementioned newspaper report that three of 15 JCU stations “picked up very slight activity in Fairfield County area.” Fr. Ott declined to call the event an earthquake because of the poor quality of his signals. None of the operating seismic stations were closer than 150 km from this event.

The Stoutsville area is not an area of active limestone quarrying or strip mining for coal, which would rule out this event being a blast. There is a possibility that it could have been a sonic boom from a military aircraft as this general area has been used for training exercises. However, there also remains the distinct possibility that this was a small earthquake with an epicenter very close to Stoutsville.



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