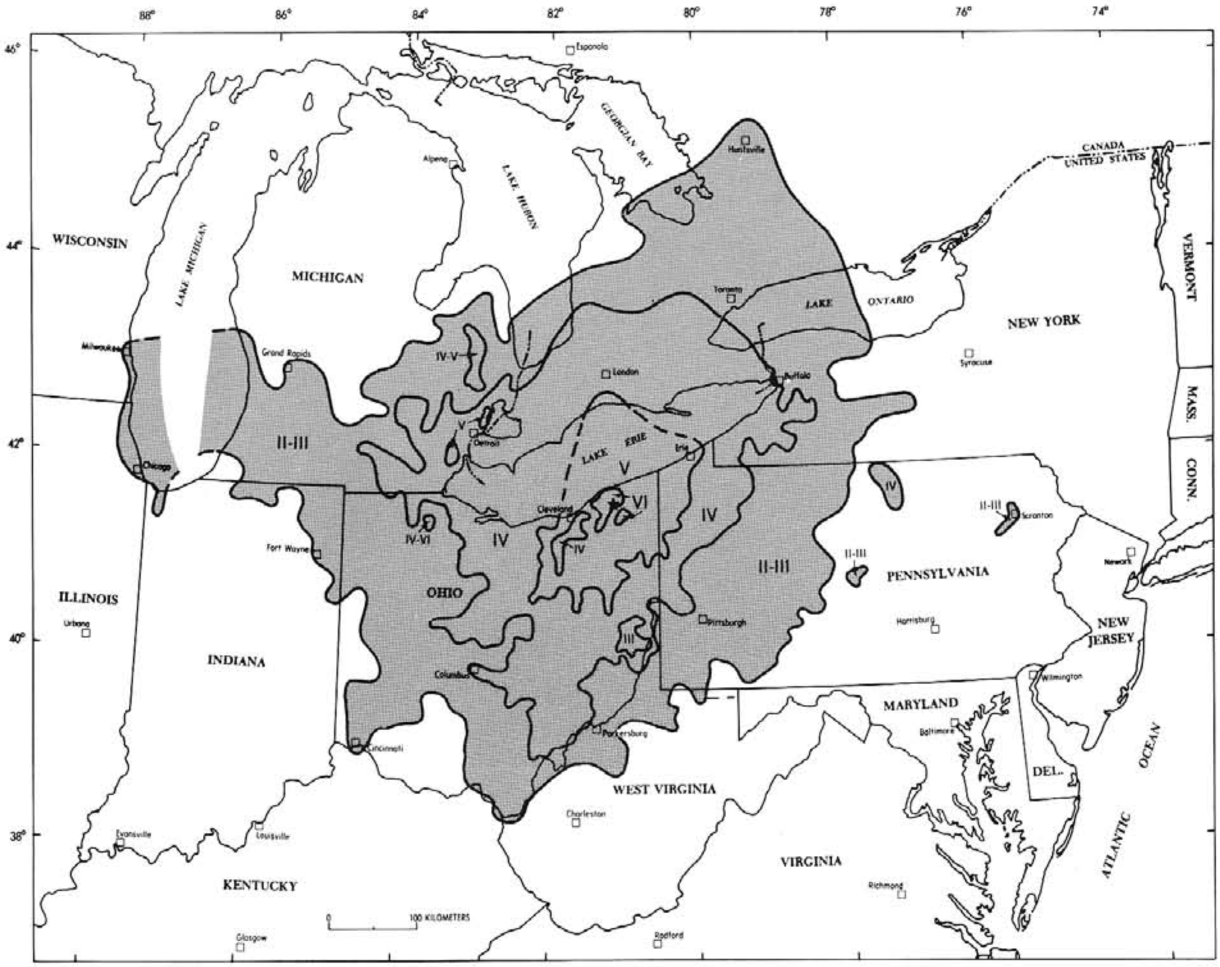
SUMMER 1986

Ohio Geology Newsletter

Division of Geological Survey

THE JANUARY 1986 NORTHEASTERN OHIO EARTHQUAKE *by Michael C. Hansen*



Isoseismal map for the January 31, 1986, northeastern Ohio earthquake. Compiled by Carl Stover, U.S. Geological Survey.

Modified Mercalli Intensity Scale

I. Not felt except by a very few under especially favorable circumstances.

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing of truck.

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 striking building. Standing motorcars rocked noticeably.

V. Felt by nearly everyone, many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.

VI. Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motorcars.

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motorcars disturbed.

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with their foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.

XI. Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into air.

continued on next page

ODNR
OHIO DEPARTMENT OF NATURAL RESOURCES

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

Chief's corner by Horace R. Collins

The Public Broadcasting System will air a seven-part series entitled "Out of the Fiery Furnace" starting Sunday, October 5 (check local listings for time). This series will show how metal resources have dominated the history of man and how man has mastered the earth's riches. Activities from the Stone Age to the Space Age will be covered.

Not only metals but all minerals have played and still play a vital role in the well-being of every individual in our society. Civilization as we know it simply could not exist without the development and use of the earth's mineral riches. The earliest inhabitants of the northeastern United States made extensive use of flint from the Flint Ridge area of Ohio to fashion weapons and simple tools. It is commonly believed that this source of flint was so important to these early Americans that by widespread tribal agreement there would be no warring in the vicinity of the flint quarries. All were free to come and go in order to exploit this valuable resource.

The earliest European settlers found sources of salt on the Ohio frontier by developing brine springs previously used by the Indian inhabitants. The increasingly large number of European settlers moving into Ohio brought with them the knowledge of the use of other mineral resources which had been developed through time in their native countries. Thus stone was quarried for homes and public construction, brick was made from native clays, coal was mined for fuel, and iron was wrought from the ores of the hills. As society became increasingly complex, new uses were discovered for minerals such as oil and gas, which gained in significance. Also, more sophisticated use was made of age-old commodities such as coal for electricity and limestone for portland cement.

If one will take the time to look about them and see the application of metals, stone (including processed materials), and fuels, it becomes apparent that mineral resources are a keystone of our society. No wonder wars have been fought over mineral resources. To gain a better appreciation of one phase of the importance of minerals, I urge the watching of "Out of the Fiery Furnace."

ISOTELUS NOTES

The Survey has added a belt buckle to the list of items commemorating a trilobite, *Isotelus,* as the official state fossil of Ohio. The brass-plated buckles are 3 inches in length and are identical to the *Isotelus* paperweights (see *Ohio Geology,* Summer 1985) except that they are lighter in weight. The buckles were produced in response to suggestions from a number of individuals that the paperweights would make attractive belt buckles if the proper fasteners were added. The buckles are priced at $5.00 each plus tax and mailing ($6.50 total for mail orders) and are available from the Survey. Additional *Isotelus* items still available include paperweights ($6.50 each), tie tacks/lapel pins ($1.25 each), and postcards (50¢ each, 10 for $3.00). All prices are for mail orders and include tax and mailing.

The Survey was recently presented with an attractive cast of Dan Cooper's 9½-inch-long *Isotelus* specimen (see *Ohio Geology,* Summer 1985) by Ron Shegitz and Dave Brown of Mid-Land Scientific Service, P.O. Box 601, Stryker, Ohio 43557. Mid-Land is in the process of reconstructing the famous Huffman Dam specimen of *Isotelus* for the Survey exhibit of Ohio trilobites.

OHIO GEOLOGY

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

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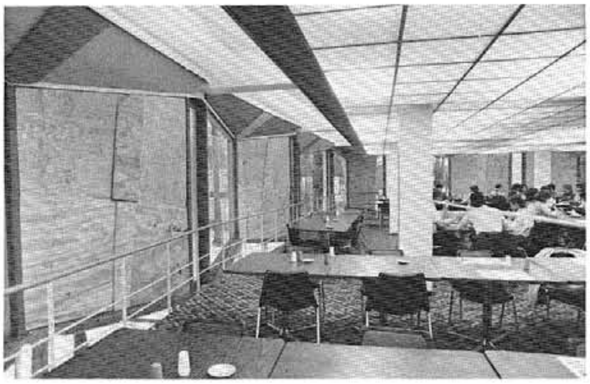
On January 31, 1986, many northeastern Ohio residents were startled into the realization that this area is seismically active; historically, the region has the second highest frequency of earthquake activity of any area of the state. Only Shelby County and vicinity in western Ohio have experienced more earthquakes in historic times. The 1986 northeastern Ohio earthquake has the distinction of being the most intensively studied Ohio earthquake, the first earthquake in the state for which injuries were recorded, and the nearest earthquake to a nuclear power plant in the United States. The 1986 event ranks as probably the third largest earthquake in Ohio.

The January 31st earthquake struck just before 11:47 a.m. Eastern Standard Time. Although early media speculation had the epicenter located from Columbus to southern Canada, the U.S. Geological Survey quickly determined that the epicenter was east of Cleveland, and within a few hours the epicenter had been accurately located in southern Lake County just north of the Geauga-Lake County line. This Richter magnitude 4.96 (commonly rounded to 5.0) event was felt in parts of 11 states, the District of Columbia, and southern Ontario. Most of Ohio and western Pennsylvania experienced particularly strong vibrations that were noted by numerous individuals. The Division of Geological Survey received hundreds of telephone calls in the hours after the earthquake as did numerous federal, state, and local agencies.

Early rumors of mass destruction, injury, and death turned out to be false. Although newspapers reported 17 people being treated for injuries in the epicentral area, only two injuries were a direct result of the earthquake. A woman received minor cuts from falling ceiling tile in a Mentor shopping mall and a child received a minor cut from broken window glass at Lake Erie College in Painesville. The remainder of the reported injuries turned out to be people treated for anxiety and effects of cold weather after they were evacuated from buildings suspected of being damaged by the quake.

Destruction in the epicentral area was mostly minor. Merchandise fell from store shelves in Mentor, Painesville, and Chardon and buildings in these communities experienced varying degrees of cracked plaster and cracked or broken windows. Chimneys are particularly susceptible to damage or destruction from ground motion associated with



Boarded windows broken by the January 31st earthquake in the dining hall at Lake Erie College, Painesville. Photo by Akron Beacon Journal.

moderate to strong earthquakes. There was, however, only one confirmed report of a chimney being toppled. Local newspapers reported several other chimneys that sustained cracks or that were pulled away from a home or building in the epicentral area. Many schools in Lake and Geauga Counties were evacuated after the earthquake and inspected for structural damage. None were reported to have sustained significant structural damage, although cracks in walls were reported at several schools.

There were numerous reports from Lake and Geauga Counties of changes in water wells. The most common effect was a change in color or taste of the well water. There were several reports of wells going dry and a few even increased their flow by a considerable rate.

Many people in northeastern Ohio initially interpreted the earthquake as an exploding furnace or a truck striking the building. Less mundane interpretations included a nuclear attack on New York City or the aftershock of the explosion of the space shuttle *Challenger* on January 28, 1986.

Perhaps the greatest concern—and controversy—was directed towards the Perry Nuclear Power Plant in northern Lake County. The plant was not operating at the time of the earthquake but was scheduled to load fuel rods on the next day. Officials at the Perry plant, which is located about 11 miles north of the epicenter, declared a precautionary site-area emergency immediately after the earthquake but downgraded this to alert status within a short time. Accelerometers on site at the Perry plant recorded accelerations as high as 0.19 to 0.23 g's; the plant is designed to withstand 0.15 g's. These higher values, however, were at high frequencies and represented only momentary peak accelerations not capable of causing significant damages. Inspections of the Perry plant after the earthquake disclosed only minor cracks in concrete and small leaks in noncritical water pipes. Both conditions may have existed before the earthquake, according to newspaper reports.

Because of an increased interest in earthquakes in the eastern United States, the comparatively large magnitude of the event, the potential for aftershock activity, and the proximity of the epicenter to a nuclear power plant, approximately 30 seismologists representing Lamont-Doherty Geological Observatory (Palisades, New York), University of Michigan, St. Louis University, Tennessee Earthquake Information Center, U.S. Geological Survey (Reston, Virginia; Denver, Colorado; Menlo Park, California), Weston Geophysical (Westboro, Massachusetts), University of Wisconsin, and Woodward-Clyde Consultants arrived at the epicentral area on the day after the earthquake. The primary objective of these seismologists was to place portable seismographs in the epicentral area in order to record aftershocks.

Although aftershocks are commonly considerably smaller in magnitude that the main event, the proximity of portable instruments deployed around the perimeter of an epicenter permits precise locations of focal depths for the aftershocks. Such numerous detailed seismic records can then be used to located the zone of rupture and define the direction of movement along the fault plane.

DATA FOR THE MAIN EVENT AND AFTERSHOCKS OF THE JANUARY 31ST NORTHEASTERN OHIO EARTHQUAKE

Date (UTC)[1]			Origin time (UTC)			Location		Richter magnitude	Depth (km)	Event
Yr	Mo	Day	Hr	Min	Sec	Lat. °N	Long. °W			
1986	01	31	16	46	42.3	41.65	81.16	4.96	8.00	main
1986	02	01	18	54	49.2	41.65	81.16	1.4	4.97	aftershock
1986	02	02	3	22	48.5	41.65	81.16	0.8	4.99	aftershock
1986	02	03	19	47	19.6	41.65	81.16	1.8	6.93	aftershock
1986	02	06	6	34	2.4	41.65	81.16	-0.3	2.07	aftershock
1986	02	06	18	36	22.2	41.64	81.16	2.4	5.89	aftershock
1986	02	07	16	20	20.2	41.65	81.15	1.0	4.64	aftershock
1986	02	10	20	6	13.5	41.65	81.16	0.9	4.97	aftershock
1986	02	23	03	29	48.5	41.65	81.16	-0.3	4.77	aftershock
1986	02	24	16	66	6.4	41.65	81.16	0.1	3.72	aftershock
1986	02	28	1	39	34.1	41.65	81.16	0.1	4.31	aftershock
1986	03	08	20	42	49.5	41.65	81.16	-0.5	4.42	aftershock
1986	03	12	8	55	26.7	41.73	81.17	-0.2	2.01	aftershock
1986	03	24	13	42	41.2	41.63	81.17	1.3	4.92	aftershock

Source: Rob Wesson, U.S. Geological Survey.

[1]UTC, Universal Coordinated Time, is equal to Greenwich Mean Time (GMT) and is used to standardize all earthquakes. To convert to local time (Eastern Standard Time) substract 5 hours (4 hours for Daylight Saving Time) from UTC. Note that events that occur in early morning hours on UTC are listed as a day later than local time.

At least 13 aftershocks (see accompanying table) occurred after the January 31st main event and were monitored by the network of portable seismographs. It is probable that additional aftershocks occurred in the hours immediately after the main shock; however, these were not recorded because it took more than 15 hours for portable instruments to reach the epicentral area from the institutions noted above. Unfortunately, no Ohio institution currently has the instrumentation or a program to quickly respond to such events. The monitored aftershocks had Richter magnitudes of -0.5 to 2.4. The latter event was felt by some individuals in the epicentral area. Studies of the aftershock data by seismologists at Lamont-Doherty Geological Observatory indicate a zone of rupture about 1 km wide, centered at a depth of about 6 km, and striking north-northeast. Fault-plane solutions based on these aftershock data indicate right-lateral strike-slip displacement on the fault. This orientation of the fault plane is consistent with the northeasterly directed axis of maximum horizontal compression that is characteristic of the regional stress field. The aftershocks tended to cluster in a pattern reminiscent of a vertical cylinder and were probably concentrated in the periphery of the main rupture.

Relatively few aftershocks were associated with the January 31st earthquake, perhaps because of a significant drop in stress after the main event. Seismologist Leonardo Seeber of Lamont-Doherty Geological Observatory suggests that faults in the eastern United States can produce larger earthquakes than similar-sized faults in the western United States. Although most of the aftershocks occurred within a few days of the main event, monitoring will continue on a reduced scale for at least two more years through a program funded by the Cleveland Electric Illuminating Company and carried out under the direction of Rev. William Ott of John Carroll University in Cleveland.

An initial concern of several geologists immediately after the January 31st event was that it may have been induced by a Calhio deep-disposal well located near the town of Perry, approximately 8 miles north of the epicenter. This well has been injecting liquid wastes from agricultural manufacturing into the Mt. Simon Sandstone at a depth of about 6,000 feet since the early 1970's. Since that time more than 300 million gallons of liquid have been injected into the Mt. Simon and Kerbel (Maynardsville), units of Cambrian age that overly the Precambrian crystalline rocks of the basement.

There are several documented cases of seismic activity being induced by injection of liquids, including the famous Denver, Colorado, series of earthquakes in the late 1960's. Geologists from the U.S. Geological Survey and several other organizations examined available data pertaining to the injection well and the earthquake but no definite correlation could be made between them. Although the involvement of the injection well in the seismic activity could not be totally ruled out, most geologists who studied the available data concluded that there was a low probability for a case of induced seismicity. The historic seismic activity in northeastern Ohio, which long predates the Calhio injection well and indeed any drilling or deep mining activity in this part of the state, suggests that seismic activity in this area is not a result of human activities.

INTENSITIES AND FELT AREA

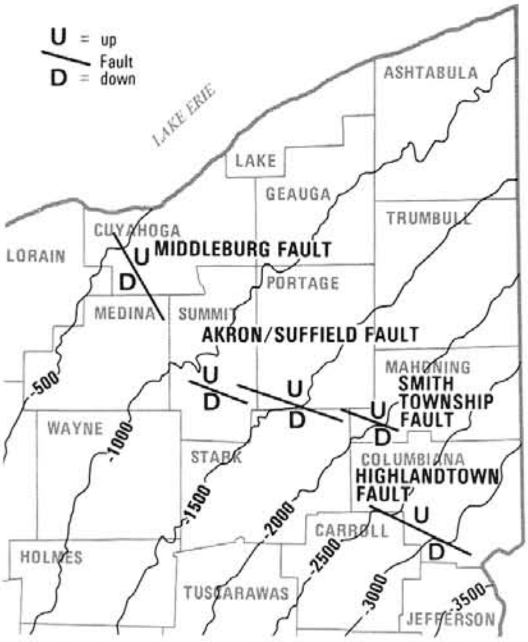
As is common and might be expected, the highest intensities for the January 31st earthquake were in the epicentral area. An onsite canvass of damages in the epicentral area by a geologist from the National Earthquake Information Center (U.S. Geological Survey, Denver) determined that the highest intensities were in the VI range on the Modified Mercalli Intensity Scale.

It is apparent from damage and felt reports that there was variation of intensities in the epicentral area. Damages in Mentor and other lakeshore communities can probably be attributed to the effect of amplification of ground vibrations by relatively thick sequences of lake clays and glacial sediments. Although it is not well documented through detailed studies, newspaper accounts and eyewitness reports to the Survey indicate that structures located above deeply buried preglacial valleys experienced higher ground motions than did similar nearby structures situated on bedrock. Such phenomena are typical of many earthquakes.

The irregularities of the isoseismal lines on the isoseismal map on page 1 are not well understood at present. The northeastward elongation of these contours into Ontario coincides with the orientation of the earthquake-generating fault and may represent a focusing of seismic energy in this direction. Various isolated pockets of higher or lower intensities at some distance from the epicentral area are poorly understood at present but are probably related to local geologic conditions.

FAULTS

In the days after the January 31st earthquake there was considerable public interest in the location of faults in the epicentral area and in northeastern Ohio in general. Many people were surprised to learn that few faults are known from surface exposures in Ohio and none are known to be exposed at the surface in northeastern Ohio. There are



Faults in northeastern Ohio as mapped by J. D. Gray from records of oil and gas wells penetrating the "Big Lime" (Silurian).

several reasons for this circumstance. It is probable that most significant faults in the state, and certainly the earthquake-generating ones, originate in the crystalline basement rocks that underlie Ohio. Many of these faults are thought to be ancient ones that were initially formed hundreds of millions of years ago. They are zones of weakness that periodically experience failure in the current stress field. It is probable that many of these basement faults do not reach the surface because they die out within the sedimentary rock sequence that overlies the basement rocks. Faults that may extend to the surface are difficult to detect because in many areas of the state outcrops of rock are limited owing to lack of relief of the land surface, a thick vegetational or soil cover, and a mantling of glacial sediment over the bedrock. In addition, many areas of the state have not been mapped, geologically, in detail, although the Survey's statewide county geologic mapping program will eventually remedy this situation.

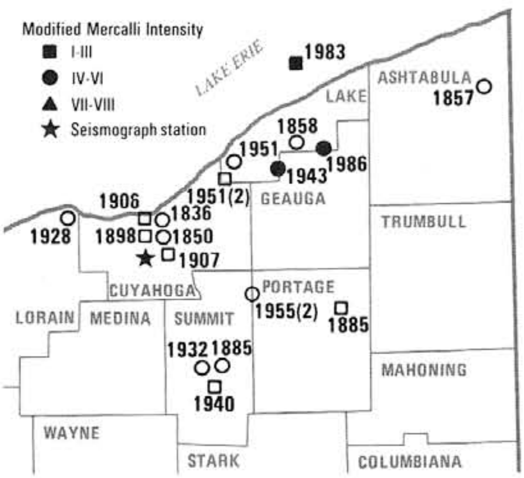
Several faults were mapped in northeastern Ohio by John D. Gray, Head of the Division of Geological Survey's Subsurface Geology Section, on the basis of oil and gas well data. No faults were detected in the epicentral area of the earthquake in this mapping study; however, there is an insufficient number of oil and gas wells in the area from which structural determinations can be made.

There was considerable publicity in some northeastern Ohio newspapers about a supposed earthquake-related geologic structure exposed along Bates Creek in Lake County. A photograph of this structure (see *Ohio Geology*, Winter 1985) was featured in Charles S. Prosser's *Devonian and Mississippian formations of northeastern Ohio,* published in 1912 (Ohio Geological Survey Bulletin 15). Recent field investigations by Weston Geophysical geologists of this and similar structures revealed the presence of more than 75 similar features in a two-quadrangle area near the epicenter of the 1986 earthquake. None of these features could be traced at depth. They are interpreted to be either stream anticlines (see *Ohio Geology*, Winter 1985), or soft-sediment deformational features formed soon after deposition of the sediments, or they possibly may be related to disturbance by glaciers of the Pleistocene ice age. These structures clearly do not have any apparent relationship to deep faults or seismic activity.

PREVIOUS EARTHQUAKE ACTIVITY IN NORTHEASTERN OHIO

At least 19 earthquakes are known to have occurred in the northeastern Ohio counties of Ashtabula (1), Cuyahoga (7), Lake (4), Lorain (1), Portage (3), and Summit (3) prior to the 1986 Lake County event. Most of these earthquakes, the earliest of which occurred in 1836, predate the availability of seismographs and are therefore located and rated as to intensity on the basis of newspaper and other historic accounts. These data have recently been researched and evaluated in detail by personnel from Weston Geophysical.

These accounts suggest that most of the previous seismic activity in northeastern Ohio was of relatively low intensity and associated with only minor and isolated damages such as a few broken windows and items falling off shelves. One earthquake, which occurred on March 9, 1943, had a Richter magnitude of 4.7 and an epicentral intensity of V. No significant damages were reported from this quake, which had a felt area of 220,000 square kilometers (85,000 square miles). This event was originally assigned a location beneath Lake Erie, offshore from Ashtabula County; however, recent re-evaluation of the seismic records of this event by seismologists from the U.S. Geological Survey placed the epicenter on the Lake-Geauga County line, near the epicenter of the 1986 event.



Historic earthquake activity in northeastern Ohio. Open symbols indicate noninstrumentally located quakes.

It should be kept in mind that the epicentral locations of all of these historic, noninstrumentally located earthquakes in northeastern Ohio are subject to some error, perhaps as great as 10 or 20 miles. A margin of error in location also applies to instrumentally located events prior to the 1986 earthquake because of the small nature of most of them and the poor distribution of seismographs. It is prudent, therefore, to avoid inferring apparent alignments of epicenters as indicating fault trends. If the January 31, 1986, event were located solely on the basis of newspaper accounts of damages, the epicenter probably would have been placed between Painesville and Mentor, two communities that reported damages. The precise location of the event was primarily the result of monitoring the location of aftershock activity with portable seismographs that were placed in the epicentral area.

Although the January 31, 1986, Lake County earthquake and its aftershocks qualify as the best documented and most thoroughly studied seismic event in Ohio, there is still little understanding of the source mechanism for this and other earthquakes in various parts of the state. Such uncertainty applies, in general, to earthquakes throughout the eastern United States.

Considerable progress has been made in the past few years in gaining knowledge of certain characteristics of the crystalline basement rocks that underlie the state. This knowledge has come principally from recently published aeromagnetic and gravity maps of the state (see *Ohio Geology*, Summer 1984); however, we are still at a rudimentary stage of understanding of the complexities of these basement rocks in which all or most Ohio earthquakes originate. Seismic networks for monitoring earthquake activity in the state are far from adequate. Only the Anna network in western Ohio, operated by the University of Michigan, is available for detailed seismic monitoring. It is supplemented by seismographs at John Carroll University in Cleveland, Bowling Green State University in Bowling Green, and the University of Toledo. The temporary installation of the northeastern Ohio network will be a welcome addition to seismic monitoring capabilities in the state; however, the proposed withdrawal of federal funding for support of seismic networks would seriously hamper the quest for knowledge about Ohio earthquakes. These events are unpredictable phenomena and a particular seismic network may record very little local seismic activity during the course of several years of operation. However, when an event such as the one of last January occurs, it is imperative that maximum data be derived from it.

FURTHER READING

Hansen, M. C., 1986, Earthquakes in Ohio: Ohio Division of Geological Survey Educational Leaflet No. 9.

Wesson, R. L., and Nicholson, Craig, eds., 1986, Studies of the January 31, 1986, northeastern Ohio earthquake: U.S. Geological Survey Open-File Report 86-331, 131 p.

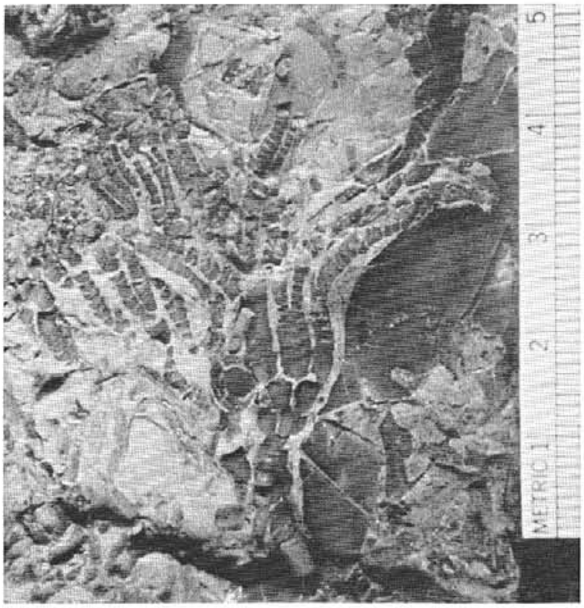
ACKNOWLEDGMENT

We thank Carl Stover and Robert L. Wesson, U.S. Geological Survey; John Armbruster and Leonardo Seeber, Lamont-Doherty Geological Observatory; Preston Turner, Weston Geophysical; and Rev. William Ott, John Carroll University, for providing information used in this article.

ORDOVICIAN ECHNINODERM FOSSILS

by Gregory A. Schumacher
Regional Geology Section

Ordovician rocks in southwestern Ohio are the oldest exposed in the state and represent a time when Ohio was covered by a warm, shallow sea that teemed with a bewildering variety of animals, many of which became entombed in the limy muds to become exquisitely preserved fossils. These abundant and well-preserved fossils were the subject of many early geologic reports including those of the Ohio Geological Survey under the direction of J. S. Newberry in the 1870's and 1880's. Since that time these fossils have been the subject of numerous additional scholarly contributions and have become famous among both professional paleontologists and amateur fossil collectors. Indeed, the alternating limestones and shales and their abundant fossils are known worldwide



Specimens of the crinoid Cupulocrinus polydactylus *illustrating the excellent preservation of Caesar Creek echinoderms.*

and many specimens from southwestern Ohio reside in collections throughout North America and Europe.

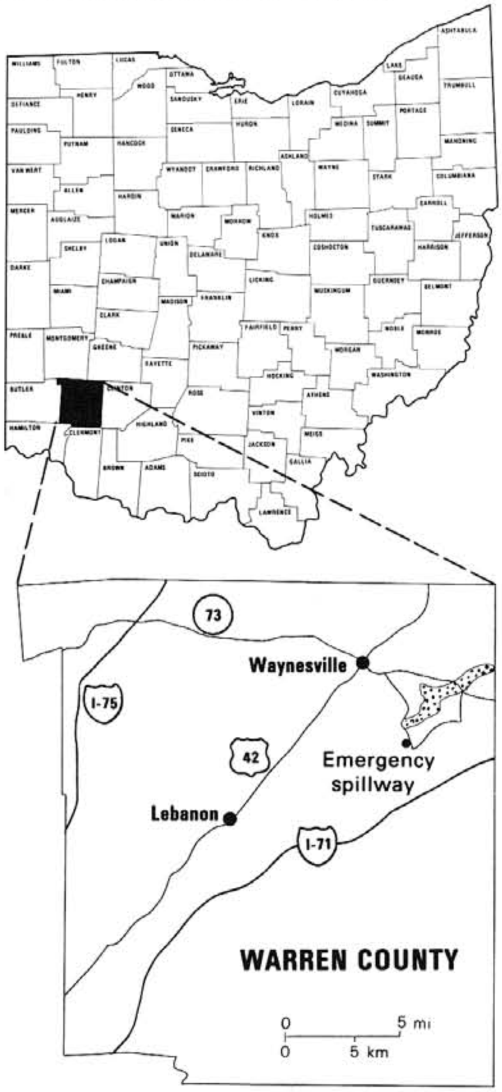
These abundant Ordovician fossils, which can literally be gathered by the bucketful at some localities, include representatives of animal groups well known as fossils, such as brachiopods, corals, cephalopods, clams, and trilobites. In addition, these rocks produce fossils of animal groups that are only rarely preserved as articulated remains. Some observations on this comparatively uncommon preservation are the subject of this article.

Animals become fossils if their skeletal components are buried soon after death. The time between an animal's death and final burial dictates whether or not it is preserved intact or as disarticulated (separate) skeletal elements. Time periods of less than one week between death and burial generally had little effect on the skeletal components of Ordovician animals known from fossils. However, Ordovician echinoderms, a group of animals represented by starfish, sea lilies (crinoids), and sand dollars, were particularly susceptible to disarticulation because of their skeletal anatomy. The echinoderm skeleton consists of hundreds of mineralized elements, termed ossicles, which are bound together by muscle and ligament fibers. Individual ossicles can be thought of as a series of individual poker chips with the muscle and ligament fibers acting as glue between them. Within one week after the death of an individual echinoderm, scavengers and decay remove the glue, thus liberating the individual ossicles. Therefore, because of the efficiency of scavengers and decay, complete echinoderms are rarely preserved.

The question then arises, how do complete, articulated echinoderm skeletons become fossils? The answer is simple: protection of individual specimens from the destructive processes created by scavengers and decay through rapid burial under a blanket of sediment.

Rapid burial of Ordovician echinoderms was achieved through the action of hurricanes or similar storms. Currents generated by these storms affected Ordovician sediments by eroding, transporting, and redepositing large quantities of sediment, much as modern hurricanes affect Recent sediments. Ordovician storms produced the influx of sediment necessary for the rapid burial and resultant preservation of complete, articulated echinoderm specimens.

Many complete, well-preserved echinoderms have been collected throughout the entire sequence of Ohio's Ordovician rocks, although historically the majority of these specimens were collected from the lower portion. The predominance of fossils from the lower part of the sequence was a direct result of the many exposures created by construction activities in Cincinnati. The few echinoderms known from Upper Ordovician rocks in Ohio were collected from isolated stream cuts in the surrounding countryside.



Map of Warren County, Ohio, illustrating the location of the Caesar Creek emergency spillway.

Recent excavations for the dam and emergency spillway at Caesar Creek Reservoir, in Warren County, have provided an excellent exposure for the study of the upper portion of Upper Ordovician rocks. These exposures have produced many complete, well-preserved echinoderms. In fact, specimens representing two varieties of starfish and many specimens representing seven varieties of crinoids have been recovered.

Preliminary research has documented the specific elevations at which complete echinoderms occur within the Caesar

Creek sequence, associated fossils, and interpretations of specific storm-generated deposits. Additional research is underway, with the aim of reconstructing the community of organisms of which the crinoids were a part and explaining several varieties of fossil preservation illustrated by the Caesar Creek sequence.

FURTHER READING

Schumacher, G. A., and Ausich, W. I., 1983, New Upper Ordovician echinoderm site: Bull Fork Formation, Caesar Creek Reservoir (Warren County, Ohio): Ohio Journal of Science, v. 83, p.60-64.

COAL ANALYSES

The Survey recently published Information Circular No. 52, *Analyses of Ohio coals, 1979-1980,* by Survey geologists George Botoman and David A. Stith. This report is part of a continuing program to chemically characterize Ohio coals and has been carried out through a cooperative agreement between the Ohio Division of Geological Survey and the U.S. Geological Survey.

The report lists standard coal analyses and major, minor, and trace element analyses for 169 coal samples collected in strip mines during 1979 and 1980. These samples represent 25 separate coal seams collected in 23 Ohio counties. Analytical data are presented in tabular form by county and by coal seam in this 26-page report. Four separate fold-out tables are also included in the report. Information Circular No. 52 is available from the Survey for $3.92, which includes tax and mailing.

WHAT'S IN A NAME?

NEW PLACE NAMES DIRECTORY NOW AVAILABLE

The subject of the "Chief's Column" last quarter, *Place names directory: southern Ohio,* is now available for purchase. This publication, Division of Geological Survey Information Circular No. 53, lists all place names which appear on the U.S. Geological Survey 7.5-minute topographic quadrangle maps for 15 counties in southern and southwestern Ohio. The counties covered in IC 53 are Adams, Brown, Butler, Clermont, Clinton, Gallia, Hamilton, Highland, Jackson, Lawrence, Pike, Ross, Scioto, Vinton, and Warren Counties. The directory includes names of streams, lakes, ridges, hollows, townships, cities, villages, communities, schools, churches, cemeteries, and other named natural and cultural features. The place names are listed by county and in alphabetical order and the name of the map or maps on which that name is found is indicated.

Geologists, surveyors, travellers, and anyone interested in geographic names will find this publication useful. The place names directory will be of special interest to genealogists. IC 53, *Place names, southern Ohio,* can be purchased from the Division of Geological Survey for $2.86, which includes tax and mailing.

Two companion place names compilations also have been published. *Place names directory: northeast Ohio* (IC 45) lists place names in Ashtabula, Columbiana, Cuyahoga, Geauga, Lake, Lorain, Mahoning, Medina, Portage, Stark, Summit, Trumbull, and Wayne Counties, and is available for $1.81, including tax and mailing. *Place names directory: southeast Ohio* (IC 49) lists place names in Athens, Belmont, Carroll, Coshocton, Guernsey, Harrison, Hocking, Holmes, Jefferson, Meigs, Monroe, Morgan, Muskingum, Noble, Perry, Tuscarawas, and Washington Counties and is available for $2.86, including tax and mailing.

1985 MINERAL INDUSTRIES REPORT

The Division of Geological Survey has released the 1985 *Report on Ohio mineral industries,* compiled by Survey geologist and mineral statistician Sherry L. Weisgarber. The 1985 report provides production, sales, and employment statistics for all of Ohio's mineral industries, which include coal, limestone and dolomite, sand and gravel, sandstone and conglomerate, clay, shale, gypsum, salt, and peat. Statistics on mineral value and wages within each mineral-commodity group and directories of mineral producers in the state are included in the report. Production and mineral-value statistics are also included for oil and gas.

The 1985 report includes some important changes and one major addition from the 1984 report. The major addition is the inclusion of a revised *Mineral industries map of Ohio.* The map shows the locations of coal mines that reported production in 1985 and the locations of all industrial-mineral operations, unless they have been declared abandoned. The changes involving coal include revising the table on *Washed Ohio coal* to include more information which is easier to read, distinguishing between the dollar value of surface and underground coal in the table on *Dollar value of coal at mine,* and including the state mine numbers for each facility in the directory of reporting coal-washing plants and associated facilities. Changes involving industrial minerals include distinguishing between production and nonproduction employment in the table on *Employment at Ohio industrial mineral operations,* and including the tonnage sold of each commodity in 1985 along with the corresponding tonnage change from 1984 in the table on *Value of Ohio industrial minerals.*

Single copies of the 1985 report and map are available from the Survey for $5.47, which includes tax and mailing. The map is available separately for $1.81, which includes tax and mailing. Also available upon request are copies of the *Errata, revisions, and additions* for the 1984 *Report on Ohio mineral industries.* A summary of revised 1984 commodity information is given below. Please contact Sherry L. Weisgarber at 614-265-6588 for further information.

REVISED SUMMARY OF 1984 OHIO MINERAL STATISTICS

Numbers that are changes from those printed in the *1984 Report on Ohio mineral industries* are in *italics*

Commodity	Total production in 1984 (tons)	Total sales in 1984 (tons)	Value of tonnage sold (dollars)	Number of mines reporting sales	Average price/ton (dollars)
Coal	*38,827,202*	*39,006,646*	*$1,269,269,261*	*293*	*$32.69*
Limestone/dolomite	*29,984,398*	*37,723,757*	*125,645,652*	115[1]	*3.33*
Sand and gravel	*16,928,568*	*30,045,790*	*90,577,606*	*270*[1]	*3.01*
Salt	4,123,229	3,824,776	35,844,802	5	9.37
Sandstone/ conglomerate	1,231,694	2,152,582	24,488,305	29[1]	11.38
Clay	689,779	867,781	4,921,116	35[1]	5.67
Shale	2,403,659	*1,923,466*	*2,504,542*	24[1]	1.30
Gypsum	212,392	212,392	2,017,724	1	9.50
Peat	8,697	20,835	96,199	5	4.62

[1]Includes some mines which produced multiple commodities.

1986 SLIDE CONTEST WINNERS

1st PLACE — Arie Janssens, Granville: erosion of crushed dolomite, Maumee Stone Company, Lucas County.

2nd PLACE — James Sellers, Aurora: Berea Sandstone, Bedford Metro Park.

3rd PLACE — Trudy L. Beal, Stow: Sharon Sandstone, Gorge Metro Park.

4th PLACE — Trudy L. Beal, Stow: Old Man's Cave, Hocking County.

5th PLACE — Wendy Dow, Medway: Spring at Yellow Springs, Greene County.

HONORABLE MENTION — Adrian Achtermann, Cuyahoga Falls; Preston S. Fettrow, Columbus; Horton Hobbs III, Springfield; Stephen Ostrander, Columbus; Ann Story, North Canton.

Although the number of entries was down slightly for this year's Ohio Geology Slide Contest, those received were of an unusually high quality. Judges for the 1986 contest were David Buchanan, geologist, U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement; Christopher Duckworth, editor, *Timeline*, the Ohio Historical Society; and Jack Pennell, Deputy Chief, ODNR, Office of Public Information & Education.

Award plaques and certificates were presented to winners at the 1986 Ohio State Fair. Prints of the winning slides were displayed at the Fair and will be displayed in the Survey lobby for the next year.

QUARTERLY MINERAL SALES, JANUARY—FEBRUARY—MARCH 1986

Compiled by Sherry L. Weisgarber

Commodity	Tonnage sold this quarter[1]	Number of mines reporting sales[1]	Value of tonnage sold[1] (dollars)
Coal	9,616,330	232	295,232,834
Limestone/dolomite[2]	5,383,529	93[3]	18,713,515
Sand and gravel[2]	2,946,028	182[3]	9,245,776
Salt[2]	946,597	4[4]	13,810,434
Sandstone/conglomerate[2]	361,492	18[3]	5,483,887
Clay[2]	165,713	23[3]	1,085,489
Shale[2]	197,889	17[3]	554,124
Gypsum[2]	53,481	1	508,070
Peat[2]	920	2	6,438

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

NEW ADDRESS FOR USGS PUBLICATIONS

As of July 1, 1986, all U.S. Geological Survey maps must be ordered from:

U.S. Geological Survey
Map Distribution
Federal Center, Building 41
P.O. Box 25286
Denver, Colorado 80225

This circumstance is the result of consolidation of the Eastern and Western Distribution Sections. Topographic maps for Ohio still may be ordered from the Ohio Division of Geological Survey.

Ohio Department of Natural Resources
Division of Geological Survey
Fountain Square, Building B
Columbus, Ohio 43224

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