2020 REPORT ON EARTHQUAKE ACTIVITY IN OHIO

compiled by Jeff Fox, Daniel Blake, and Jacqueline Thompson

OHIO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES

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STATE OF OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL SURVEY
D. Mark Jones, Chief

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PREFACE

The 2020 Report on Earthquake Activity in Ohio continues the efforts of the Ohio Department of Natural Resources (ODNR) Division of Geological Survey's Ohio Seismic Network (OhioSeis) to present a clear and concise representation of all seismicity, natural and anthropogenic, in the state for the calendar year. This report presents the data in tables and figures, with brief discussions of significant earthquakes or seismic swarm activity. The computer program HYPOINVERSE-2000 (Klein, 2002) was used to process earthquake data in SEISAN and AQMS. The earthquake listing in table 3 (p. 7) is estimated to be systematically complete above magnitude 1.5 M_L within the state for 2020. However, these data are preliminary—both the locations and magnitudes in this table are subject to revision. The catalog may include some anthropogenic seismic events not yet identified.

The Ohio Earthquake Epicenters Locator interactive map is continually updated and is available for viewing at **https://gis.ohiodnr.gov/MapViewer/?config=Earthquakes**. Seismic station lists and locations are current to the calendar year of this report only. Seismic station information can also be found on the interactive map. Station metadata is available from the IRIS Data Management Center (DMC). Station locations contained within this report are not accurate for privacy purposes. Interested scientists can obtain detailed location information for performing earthquake locations from the IRIS DMC.

A complete copy of this report, including maps and earthquake catalog, is available on the ODNR Earthquakes website at **ohioseis.ohiodnr.gov**.

Jeff Fox
Seismologist

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ABBREVIATIONS USED IN THIS REPORT

Units of Measure

kilometers . . . . . km
meters . . . . . m
miles . . . . . mi

Other

Advanced National Seismic System . . . . . ANSS
ANSS Quake Management System . . . . . AQMS
Community Internet Intensity Maps . . . . . CIIM
Incorporated Research Institutions for Seismology . . . . . IRIS
Magnitude[1] . . . . . M_L or M_d
Ohio Seismic Network . . . . . OhioSeis
SEISmic ANalysis software . . . . . SEISAN
United States Geological Survey . . . . . USGS

[1]Richter local magnitude (M_L) or coda magnitude (M_d) determined by OhioSeis.

EARTHQUAKE ACTIVITY IN OHIO
JANUARY 1–DECEMBER 31, 2020

During the period January 1 through December 31, 2020, the Ohio Seismic Network (seismic network code: OH) located 30 earthquakes within the Ohio region (table 1 and fig. 1). The total includes seven earthquakes of magnitude 2.0 M_L or greater, two of which are equal to or greater than magnitude 2.5 M_L. Four of these earthquakes were felt by Ohioans[1]. A cumulative tabulation of earthquakes during 2020 that were either felt in the Ohio region or for which a Community Internet Intensity Map (CIIM) was produced, or both, is available in table 2[2]. Additional information on earthquakes within the Ohio region is available from the Ohio Seismic Network online database.

[1]Another earthquake was reported felt in Ohio but occurred in Kentucky and is therefore excluded from the data presented in table 1.
[2]A CIIM summarizes the responses, and an intensity number is assigned to each ZIP code for which a CIIM questionnaire is completed. The intensity values in each ZIP-code area are averaged, and the map is updated as additional data are received. ZIP-code areas for which data have been received are color-coded according to the intensity scale below the map; other areas are gray. A CIIM is automatically made after each widely felt earthquake in the United States. The system can start receiving responses about 3 minutes after the earthquake. Internet users can also enter data for U.S. earthquakes they have experienced in the past.

TABLE 1. ***Earthquake magnitude statistics for calendar year 2020, all of Ohio***

2020 Ohio Earthquakes Summary	
Earthquakes (all magnitudes)	30
Earthquakes ≥ M2.5	2
Earthquakes M2.0–M2.4	5
Earthquakes ≤ M1.9	23
Earthquakes receiving Felt Reports	4

FIGURE 1. Earthquake epicenters located by the Ohio Seismic Network seismograph stations in 2020.

NOTABLE EARTHQUAKE EVENTS, JANUARY 1–DECEMBER 31, 2020

During the report period, seismic activity was recorded in the three distinct seismic zones within the state: the northeast Cleveland/Lake County region, the Rome Trough region of southern and southeastern Ohio, and the Anna Seismic Zone in Shelby and Auglaize Counties. These three zones contributed the largest magnitude earthquakes recorded in the state in the year 2020.

It could be inferred that the April 7, 2020, earthquake in Lake County (fig. 2) was an aftershock of the June 10, 2019, M_L 4.2 earthquake as it occurred near the larger 2019 earthquake's epicenter. The June 2019 sequence was followed by aftershock activity into December of 2019 (Yao and others, 2021).

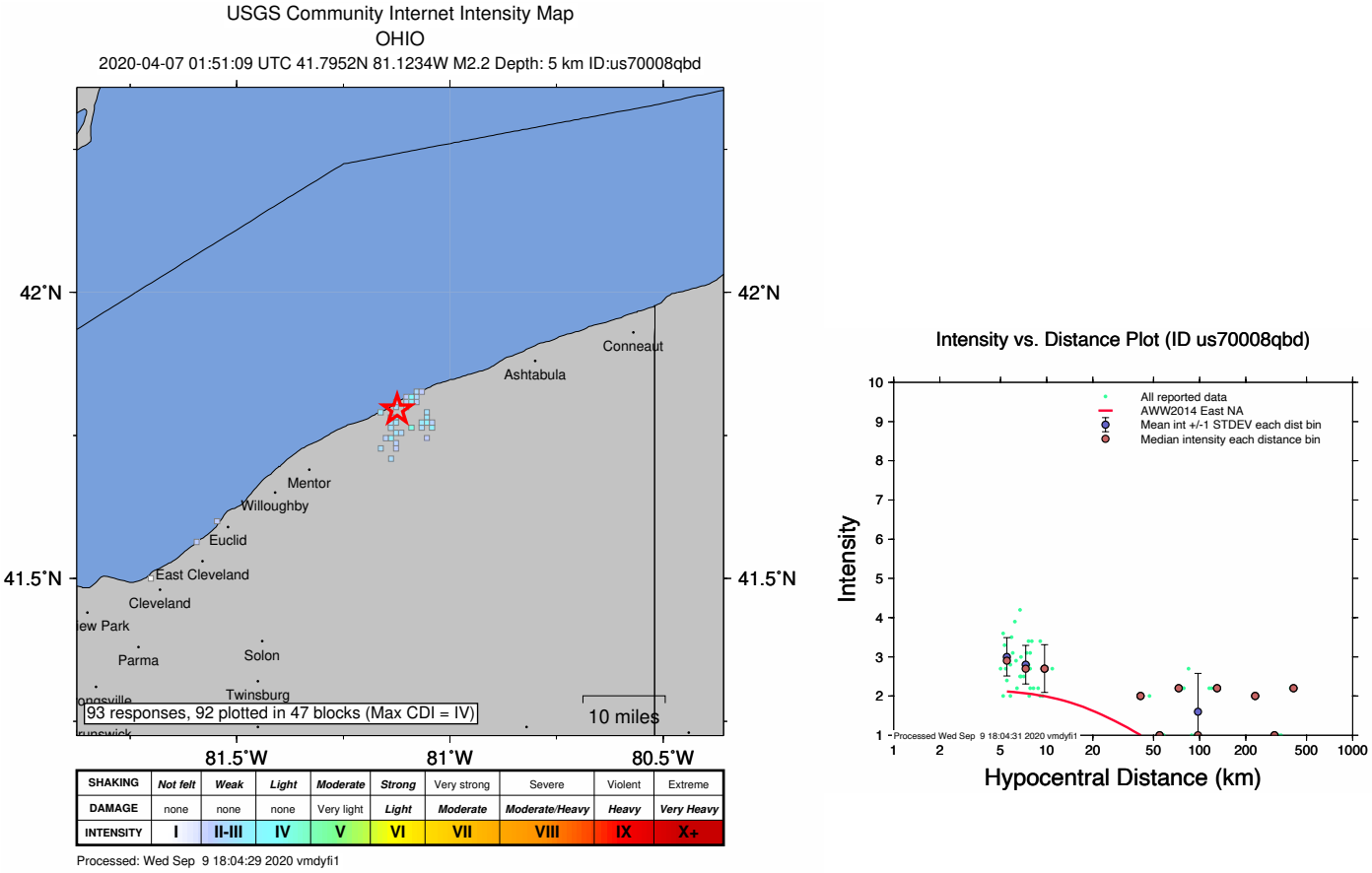
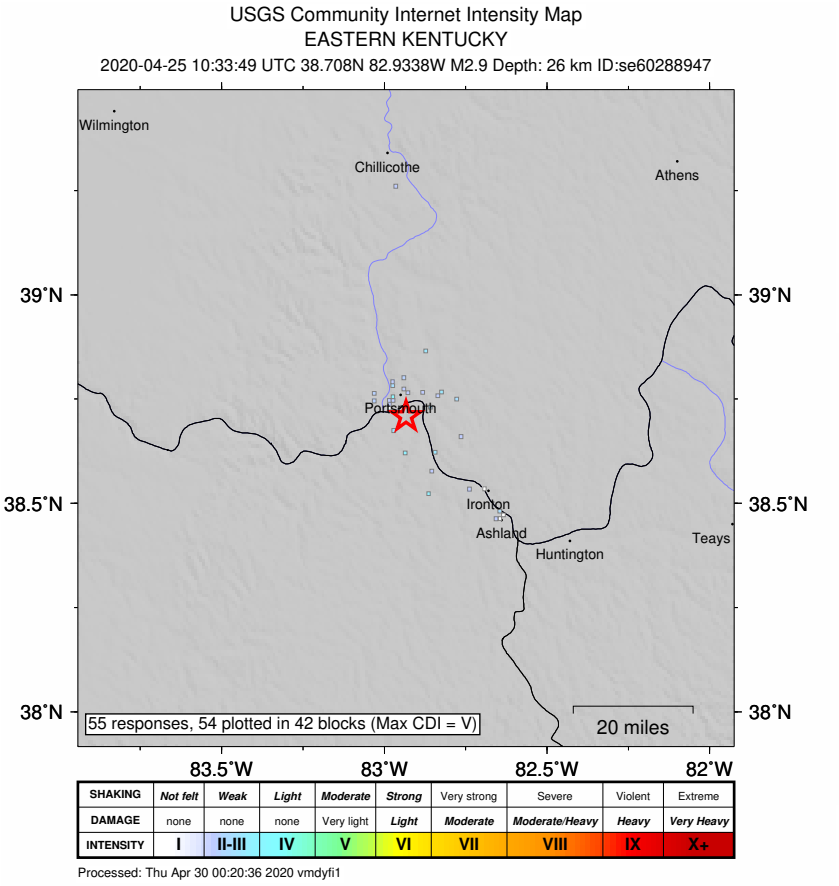


FIGURE 2. Community Internet Intensity Map (CIIM) and intensity versus distance plot for the Lake County, Ohio, earthquake of April 7, 2020.

The second region having recorded earthquakes is the southern Rome Trough area, interpreted by geologists as a failed continental rift valley that originated during the Cambrian Period. Two earthquakes were recorded in this area in 2020. The first was a M_L 2.9 earthquake located just south of the Ohio River in Greenup County, Kentucky, on April 25 (fig. 3). This earthquake was felt in parts of southern Ohio. The second event was in Scioto County on October 8 and was magnitude 2.3 M_L. Both earthquakes had deep foci of 26.9 km (USGS, 2020) and 16.7 km respectively. Earthquakes in this region have notably deeper foci than earthquakes in any other part of the state as a result of geological basement structural trends (Baranoski, 2013).



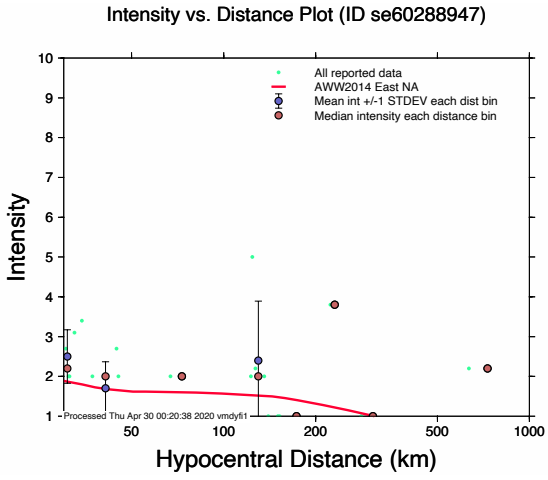
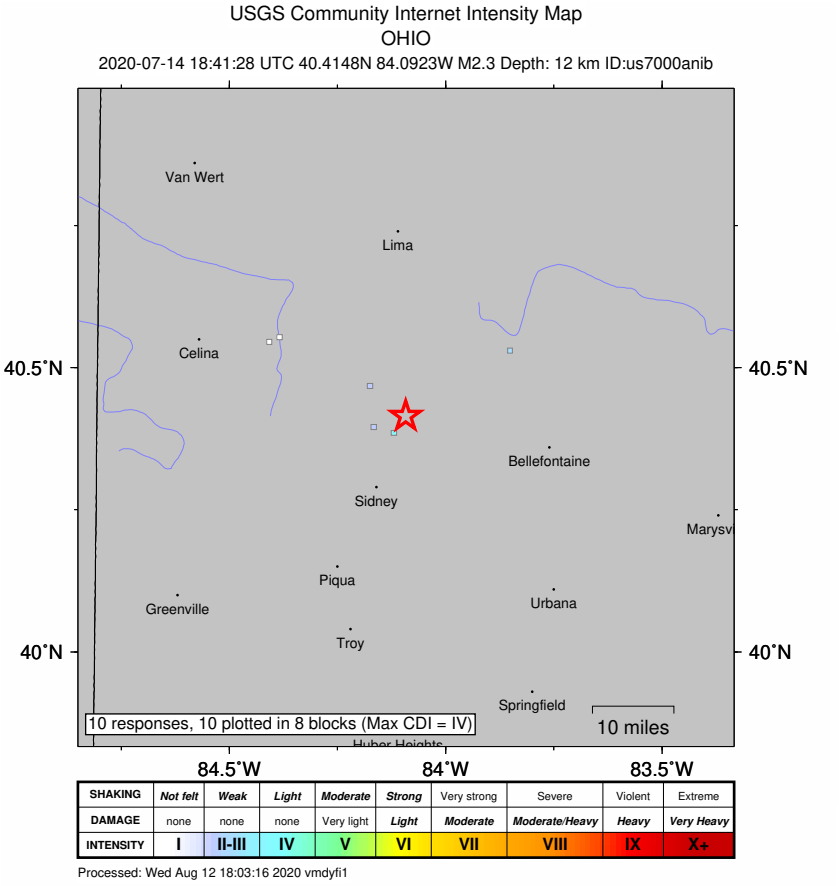


FIGURE 3. Community Internet Intensity Map (CIIM) and intensity versus distance plot for the Greenup County, Kentucky, earthquake of April 25, 2020.

Two felt earthquakes occurred in the Anna Seismic Zone in 2020 on July 14 located within a relatively small area bounded by the towns of Jackson Center, Botkins, and Anna. The first earthquake could be considered a foreshock to the second event; however, more analysis is necessary to define more clearly each earthquake's location relative to the other. The first earthquake occurred 18 minutes before the mainshock and was magnitude 1.6 M_L. The mainshock was a 2.5 M_L event and was felt over a slightly wider area. Earthquake activity in this region has been documented as far back as 1928 and was the site of Ohio's largest recorded earthquake, which occurred in 1937 (Hansen, 2017).



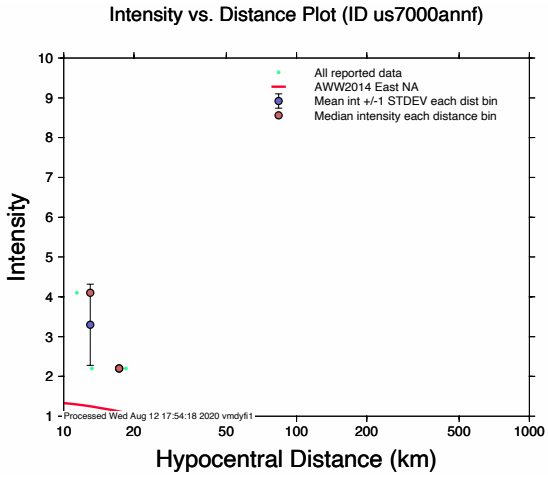


FIGURE 4. Community Internet Intensity Map (CIIM) and intensity versus distance plot for the Shelby County, Ohio, M2.5 earthquake of July 14, 2020.

FELT EARTHQUAKE EVENTS, JANUARY 1–DECEMBER 31, 2020

For earthquakes M_L 3.0 and larger in the Ohio region, the U.S. Geological Survey (USGS) automatically posts a Community Internet Intensity Map (CIIM) on its "Did You Feel It?" web page at http://earthquake.usgs.gov/earthquakes/dyfi/. Earthquakes of smaller magnitude that are felt and those reported by regional seismic networks will also be posted to the USGS CIIM pages. We encourage anyone who feels an earthquake to report their observations on this interactive website. Felt information is available by zip code on the CIIM site or can be obtained directly from OhioSeis.

TABLE 2. ***Earthquakes felt and/or generating a Shakemap in the Ohio region, January 1–December 31, 2020***

DATE	TIME[1]	FELT INFORMATION[2]	LATITUDE	LONGITUDE	MAGNITUDE (M_L)[3]
Apr 7	21:51 EST (Apr 6) 01:51 UTC	USGS ShakeMap. CIIM. Felt (III) Perry, OH and (II) Mentor, OH.	41.795 N	81.123 W	2.5
Apr 25[4]	06:33 EST 10:33 UTC	USGS ShakeMap. CIIM. Felt (II) Chillicothe, Portsmouth, OH and (III) Minford, Wheelersburg, OH.	38.708 N	82.934 W	2.9
Jul 14	13:23 DST 18:23 UTC	USGS ShakeMap. CIIM. Felt (IV) Anna, OH and (III) Jackson Center, OH.	40.440 N	84.087 W	1.6
Jul 14	13:41 DST 18:41 UTC	USGS ShakeMap. CIIM. Felt (IV) Cincinnati, OH and (III) Anna, OH.	40.417 N	84.088 W	2.5

[1]Times are listed both as Local Time—Eastern Standard Time (EST) or Eastern Daylight Time (DST)—and as Coordinated Universal Time (UTC).
[2]CIIM is Community Internet Intensity Map (http://earthquake.usgs.gov/earthquakes/dyfi), compiled by the U.S. Geological Survey (USGS); ShakeMap indicates the availability of computer-generated maps of ground shaking (https://earthquake.usgs.gov/earthquakes/search/), produced by the OhioSeis Seismograph Stations (OH). Roman numerals correspond to the Modified Mercalli intensity scale (see fig. A-4). Unless otherwise indicated, felt information is from the USGS (1) CIIM reports and/or (2) PDE Monthly (or) Weekly Listing Files (http://earthquake.usgs.gov/data/pde.php).
[3]Richter local magnitude (M_L) or coda magnitude (M_d) determined by OhioSeis.
[4]The April 25, 2020, earthquake epicenter is in the state of Kentucky, just across the Ohio River from Scioto County, Ohio, though widely felt in Ohio.

TABLE 3. ***Catalog of all earthquakes in Ohio in 2020[1]***

Year	Month	Day	Hour[2]	Minute	Second	Latitude	Longitude	Depth[3] (km)	Mag
2020	1	21	15	10	40.2	39.191	-82.541	15.0	2.0
2020	2	3	15	15	30.3	39.640	-81.543	6.0	0.8
2020	2	3	15	16	35.4	39.658	-81.513	6.0	1.0
2020	2	23	8	20	33.8	39.547	-81.806	8.2	1.8
2020	2	26	14	1	23.0	40.271	-81.236	1.1	0.0
2020	3	14	4	43	11.5	40.491	-84.291	5.0	0.3
2020	3	23	17	20	33.7	39.240	-81.723	5.0	0.7
2020	4	7	1	51	9.8	41.785	-81.115	2.5	2.5
2020	6	30	14	13	53.0	40.649	-83.848	5.0	2.0
2020	7	10	1	30	42.4	39.383	-81.384	3.2	1.1
2020	7	14	18	23	27.6	40.433	-84.105	3.0	1.6
2020	7	14	18	41	29.1	40.421	-84.109	2.4	2.5
2020	8	1	23	44	37.2	40.563	-81.008	2.0	1.5
2020	8	3	2	51	47.9	40.484	-80.886	2.1	2.0
2020	8	3	14	55	29.3	40.438	-84.102	3.0	1.4
2020	8	8	17	5	52.0	40.283	-81.142	1.1	1.2
2020	8	10	3	4	56.4	40.290	-81.159	5.0	1.8
2020	8	15	10	46	32.7	41.697	-81.120	5.0	1.2
2020	8	23	22	17	43.7	38.664	-82.805	16.7	1.5
2020	9	9	19	21	23.5	40.287	-81.145	2.2	1.7
2020	9	9	23	6	49.5	40.288	-81.143	2.0	1.7
2020	9	9	23	49	16.6	40.285	-81.145	3.2	1.2
2020	9	10	0	0	44.7	40.286	-81.145	2.2	0.3
2020	9	10	0	7	6.8	40.277	-81.148	1.0	1.7
2020	9	10	0	15	55.0	40.281	-81.141	5.0	0.4
2020	9	10	3	39	14.5	40.283	-81.144	1.1	1.4
2020	9	10	22	52	58.3	40.286	-81.147	2.1	1.6
2020	10	8	7	50	51.1	38.821	-82.770	11.0	2.3
2020	10	15	18	53	11.7	40.044	-81.232	5.0	1.8
2020	12	28	22	26	57.0	38.846	-82.173	5.5	2.0

[1]Earthquakes listed in chronological order. All magnitudes are M_L unless denoted otherwise.
[2]UTC: Coordinated Universal Time. All earthquake origin times are given in UTC time by hour. UTC is similar to GMT (Greenwich Mean Time). To convert to local time, subtract 5 hours for Eastern Standard Time (EST) and 4 hours for Daylight Saving Time (DST).
[3]Earthquake depth listed in km below datum.

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- Dr. Seth Carpenter, University of Kentucky, Kentucky Seismic Network, Lexington, Kentucky
- Dr. Yihe Huang, University of Michigan, Ann Arbor, Michigan
- Ohio Department of Natural Resources, Division of Oil & Gas Resources Management
- United States Geological Survey
- Incorporated Research Institutions for Seismology

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APPENDIX

Seismic Network Discussion

Maintenance performed

Several seismic station vaults flooded in 2020 and had to be reinstalled. OhioSeis staff determined that the water was infiltrating the barrel at the point of entry for the power cables. The original design had 2" schedule-40 PVC pipe entering a bulkhead fitting in the barrel's side. Diurnal and seasonal contraction and expansion of clay-rich soils and the plastic PVC pipe itself weakened the barrel-pipe interface and compromised the sealants, allowing water to enter the vaults.

During the summer of 2020, OhioSeis staff completed full inspections of every site and a redesign of the surface vaults. Staff found flooded vaults at BGOH, CHWO, KDOH, MFOH, MWLO, SSFO, and SLSO (see table A-1 for station locations). The instruments were pulled out of the flooded vaults and temporarily installed into the bottom shelf of the battery box while a new design was created.

The new surface vault (fig. A-1) design utilizes a taller (but narrower) barrel with a steel lock-ring on the lid. Instead of using rigid PVC pipe, staff used a flexible rubberized conduit. Also, the cable/hose entry into the taller vault was kept above grade to reduce the risk of water infiltration. Finally, a piece of outdoor pond-liner was draped over the vault's lid and then covered in a thick layer of mulch to prevent diurnal heating and to dampen noise from wind or rain. Other routine maintenance was performed throughout the network as COVID-19 protocols allowed.

FIGURE A-1. A newly redesigned OhioSeis surface vault, installed in 2020.

Station moves, station renaming, and a new station

Seismic station SSFO was moved approximately 3.7 miles to the southeast of its original location and renamed SSF2 in October 2020 (fig. A-2). Also of note, in cooperation with the University of Michigan, a broadband seismometer (designated as station BASS) was placed in the basement of the lighthouse on South Bass Island to monitor seismic activity in the western basin of Lake Erie in late 2019. Several trips were made in 2020 to update the seismometer, download earthquake data from Lake Erie's western basin, and perform routine maintenance. A Guralp 3T and RefTek RT-130 digitizer were used at this site for the duration of the Lake Erie Earthquake exPeriment (LEEP). For more information on this project, visit the LEEP website at **https://sites.lsa.umich.edu/yihehuang/lake-erie-earthquake-experiment/**.

FIGURE A-2. OhioSeis seismic station SSF2 (formerly station SSFO) at its new location in Shawnee State Forest.

TABLE A-1. ***Ohio Seismic Network operating seismograph stations as of December 31, 2020***

STATION NAME		COUNTY	INSTALLED	SENSOR	DIGITIZER	MODEM
BCOH	Blue Creek Metro Park	Lucas	2019	GURALP CMG-6TD	Onboard	RV50
BGOH	BGSU Firelands	Erie	2019	GURALP CMG-6TD	Onboard	RV50
BSPO	Barkcamp State Park	Belmont	2018	GURALP CMG-6TD	Onboard	RV50
CHWO	Cooper Hollow State Nature Preserve	Jackson	2018	GURALP CMG-6TD	Onboard	RV50
CPOH	Chaparral Prairie State Nature Preserve	Adams	2019	GURALP CMG-3T	Reftek RT 130	RV50
KDOH	Killdeer Plains Wildlife Area	Wyandot	2019	SERCEL L22 3D	Reftek RT 130	RV50
KLOH	Kiser Lake State Park	Champaign	2019	GURALP CMG-6TD	Onboard	RV50
LEBO	Lake Erie Bluffs Metro Park	Lake	2016	GURALP CMG-6TD	Onboard	RV50
M53A	Farmdale, OH	Trumbull	2018	NANOMETRICS Trillium 240	Q330	RV50
MFOH	Malabar Farms State Park	Richland	2019	GURALP CMG-3T	Reftek RT 130	RV50
MWLO	Mercer Wildlife Area	Mercer	2018	GURALP CMG-6TD	Onboard	RV50
O53A	Freeport, OH	Harrison	2018	STRECKEISEN STS-2	Q330	RV50
P51A	Williamsport, OH	Ross	2018	NANOMETRICS Trillium 240	Q330	RV50
P52A	Corning, OH	Perry	2018	STRECKEISEN STS-2	Q330	RV50
SLSO	Stonelick State Park	Clermont	2018	GURALP CMG-6TD	Onboard	RV50
SROH	Shade River State Forest	Meigs	2019	GURALP CMG-3T	Reftek RT 130	RV50
SSF2*	Shawnee State Forest	Scioto	2016	GURALP CMG-6TD	Onboard	RV50
SSPO	Sycamore State Park	Montgomery	2019	GURALP CMG-6TD	Onboard	RV50
VLOH	Vernon A. Luthman Tecumseh Wildlife Area	Shelby	2019	SERCEL L22 3D	Reftek RT 130	RV50
* SSFO was relocated and renamed to SSF2 on October 28, 2020.						

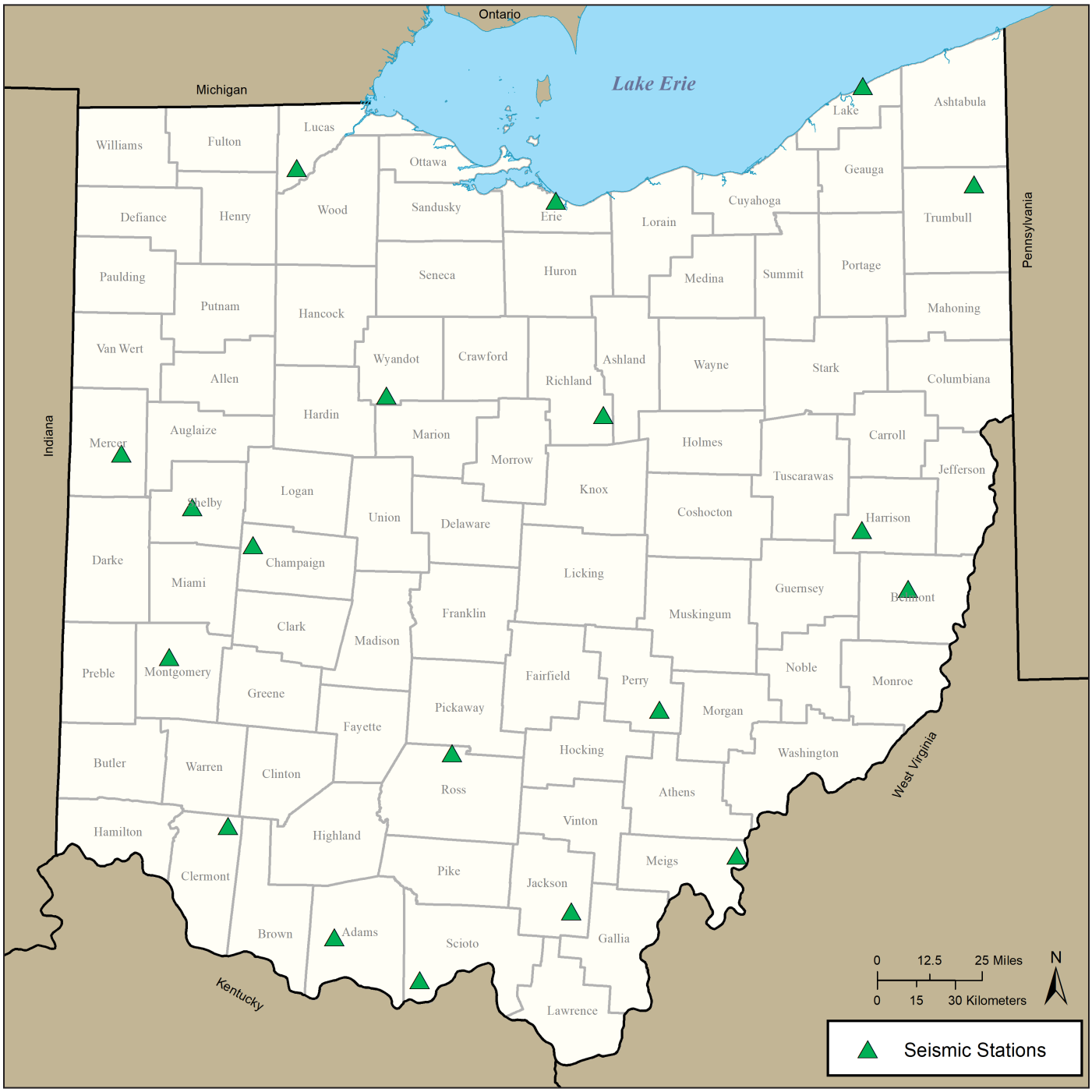

FIGURE A-3. Ohio Seismic Network station locations map for 2020.

Intensity	Shaking	Description/Damage
I	Not felt	Not felt except by a very few under especially favorable conditions.
II	Weak	Felt only by a few persons at rest,especially on upper floors of buildings.
III	Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Light	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Very strong	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII	Severe	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Violent	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

FIGURE A-4. The Modified Mercalli Intensity Scale for earthquake shaking.

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