The Ohio Seismic Network

Michael C. Hansen
Ohio Geological Survey

Larry J. Ruff
University of Michigan

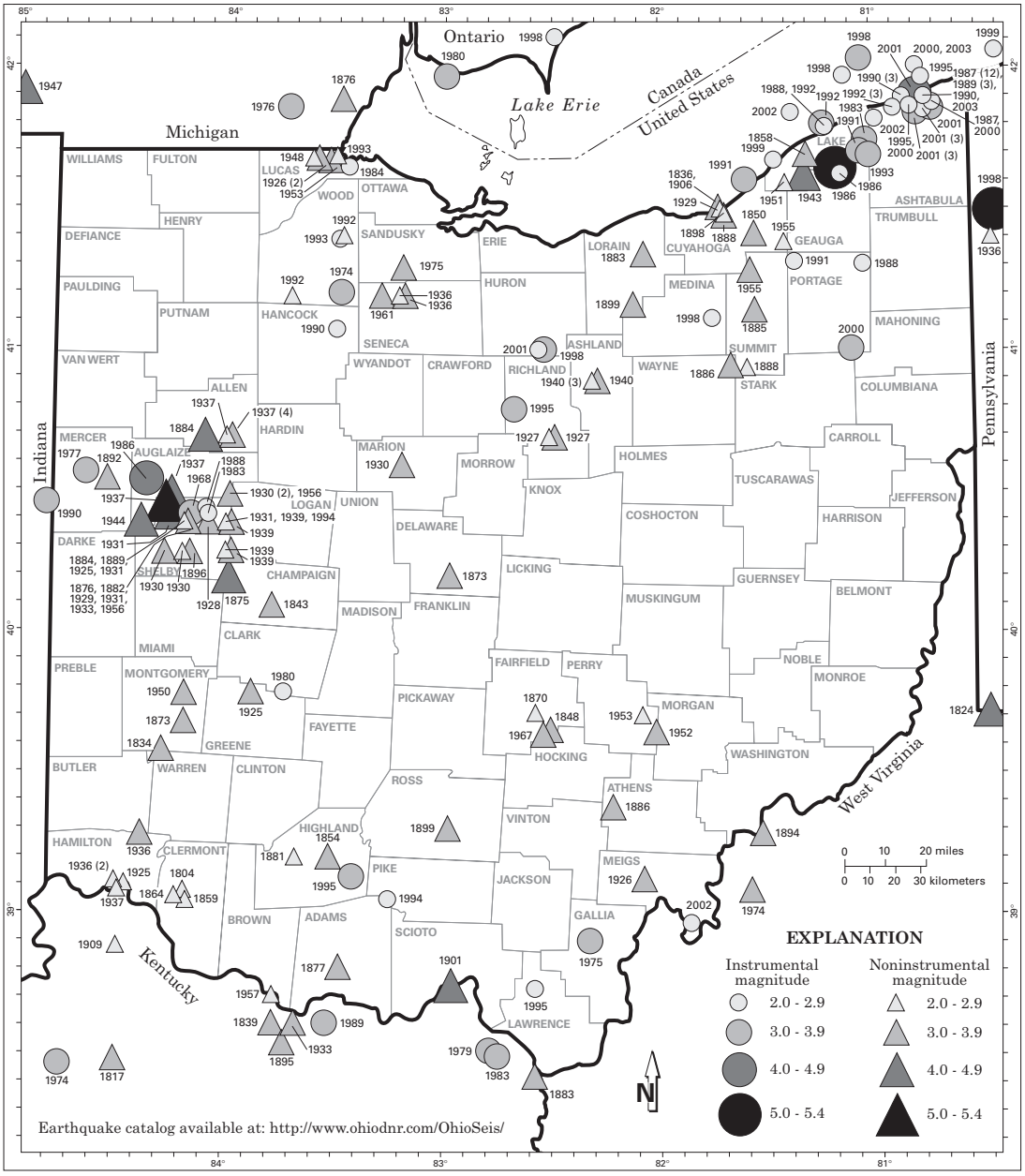
In January 1999, the Ohio Seismic Network (OhioSeis) began operations with an initial deployment of 15 stations at colleges, universities, and other institutions in various parts of the state. Funding for the network was provided by the Ohio Emergency Management Agency with Federal Emergency Management Agency Funds for earthquake mitigation. The Ohio Geological Survey assumed the responsibility for organizing, managing, and coordinating the network, and data analysis. The primary mission of the network is to detect and precisely locate earthquakes within the state's borders, report the severity and potential damage from an event to emergency response officials, and to rapidly respond to media and citizen inquiries after a felt earthquake. Both the media and the public have quickly become dependant on the Ohio Seismic Network to be the primary source of information after an event. Secondary but important goals of both the Ohio Geological Survey and the Ohio Emergency Management Agency are to evaluate seismic risk and to educate citizens about earthquake hazard in the state.

The establishment of seismic stations at various educational institutions has provided a valuable experience to students who commonly witness real-time arrival of seismic waves from large teleseismic events. Many of the geology instructors who host stations have developed educational exercises on earthquakes based on the seismic events recorded at their stations and several in-state educational institutions have developed student exercises based on the information available on the Ohio Seismic Network Web site. There has been the added educational bonus of local-station media attention after a local felt earthquake or a devastating teleseismic event. This has brought positive publicity to the local host institution and generated a sense of pride and earthquake awareness in the local community. The public visibility of the Ohio Seismic Network has increased earthquake awareness in the state and has been an integral factor in educating citizens about seismic risk.

The extensive OhioSeis Web site (http://www.ohiodnr.com/OhioSeis) includes generalized educational information, technical information on recent local and regional earthquakes, an extensive chronological catalog of in-state and border-region events, epicenter and basement structure maps of Ohio, and a link to the U.S. Geological Survey Community Internet Intensity Maps Web site for citizens to report felt earthquakes. The OhioSeis Web site also includes a link to a "technical" page that has station codes and coordinates, links to each station's data files, instructions on use of Ohio Seismic Network waveform-viewing software, and downloads for station operators.

In general, it is difficult to convince citizens in the eastern half of the United States that earthquakes are a threat in some areas to both people and property. Long recurrence intervals between significant, damaging events have created the perception among many people that earthquakes have zero probability in their area. Many Ohioans are surprised to learn that the state has experienced at least 170 earthquakes of 2.0 magnitude or above (Figure 1) since 1776 (Hansen, 2002). Of these events, 15 are documented to have caused minor to moderate damage. The most severe events were on March 2 and March 9, 1937, in western Ohio near the town of Anna. These earthquakes were estimated to have had felt-area magnitudes of 5.0 and 5.4, respectively (Stover and Coffman, 1993). Nearly every chimney in Anna was damaged by the larger shock, which had an MMI of VIII. About 40 felt earthquakes have occurred in the Anna, Ohio, area since 1875. At least 30 felt earthquakes have occurred in northeastern Ohio, and an additional 39 events of 2.0 magnitude or above, many of which were felt, have occurred in the vicinity of Ashtabula since 1987.

Ohio has a long history of seismic monitoring. The Reverend Frederick L. Odenbach, S. J. installed the first instrument in 1900 at John Carroll University (then St. Ignatius College) in Cleveland, and began what would later become the Jesuit Seismological Association. In 1927, a Jesuit station was established at Xavier University in Cincinnati, which functioned until the late 1960's (Hansen, 2000). Bowling Green State University in Bowling Green operated a station in the 1970's and 1980's. From 1977 to 1992, the Anna Seismic Network, funded by the Nuclear Regulatory Commission and managed by the University of Michigan, operated in western Ohio. From 1986 to 1992, John Carroll University operated a network in northeastern Ohio, deployed after the January 1986 earthquake (m_{bLg} 5.0) near the Perry Nuclear Power Plant in Lake County. The University of Toledo has operated an intermittently active station since the early 1980's.



▲ **Figure 1.** Epicenters of Ohio and border-region earthquakes.

In 1992, all seismic monitoring, except for the University of Toledo station, ceased in Ohio. The Ohio Seismic Hazards Advisory Board was established in 1991, with representation from various departments of state, academia, and private industry, to make recommendations to the governor about seismic risk in the state. One of the first recommendations of the board was to re-establish seismic monitoring in Ohio. Despite repeated attempts, no funding was secured.

In 1998, the Ohio Emergency Management Agency procured funds from the Federal Emergency Management Agency for earthquake mitigation in Ohio. The Ohio Emergency Management Agency graciously offered the Ohio Geological Survey modest funding to establish a seismic network.

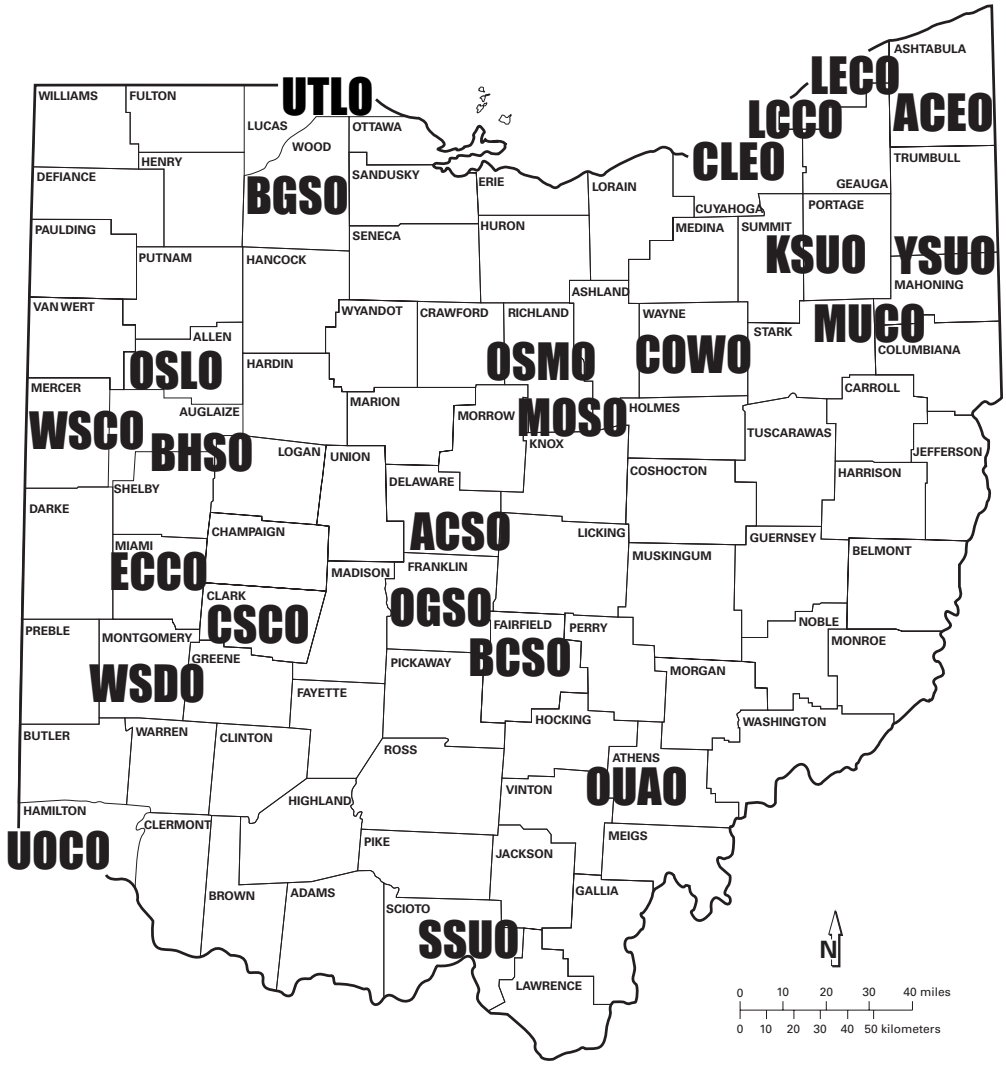
Because of modest funding for instrument acquisition, site development, and data access, and the need for a user-friendly system that could be operated by station hosts with little previous seismological experience, it was decided to utilize a hardware-software system developed by Larry J. Ruff at the University of Michigan and previously deployed in limited fashion in Michigan as the MichSeis Network. This system has the advantages of low acquisition and installation costs, comparatively simple operation and maintenance, and essentially no cost for data transmission.

The MichSeis and OhioSeis systems use a Macintosh computer for data recording, display, and analysis, a GPS receiver for time synchronization, and an Engineering Acoustics, Inc., model S102 vertical, broadband seismom-

eter. The recording computer at each station also functions as a Web server, thus making digital data available via the Internet in near-real time. Hourly data files are in AH ASCII format and can be downloaded, viewed, manipulated, filtered, and analyzed with a Macintosh computer, using a free software program, or downloaded to a Windows® spreadsheet program for viewing.

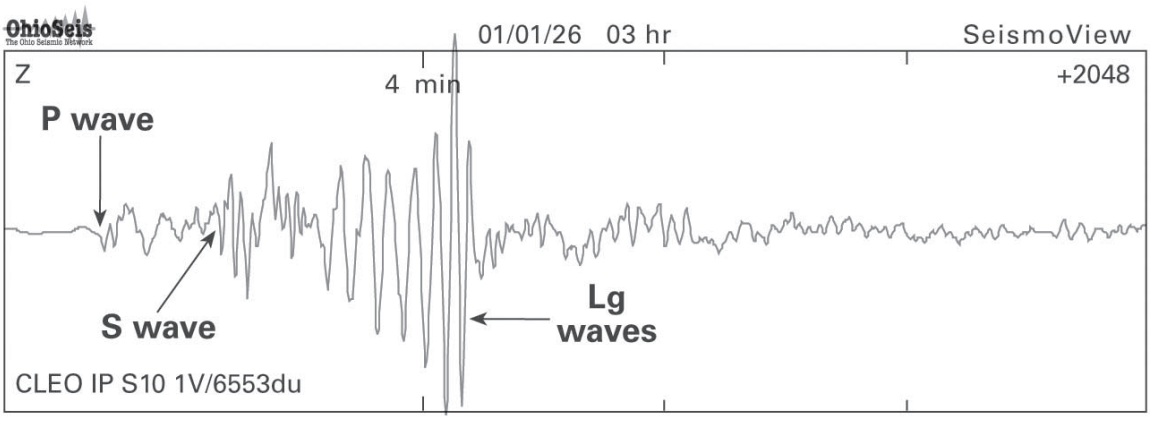
Stations were sited in seismically advantageous areas of the state, primarily at colleges and universities who were willing volunteer hosts and who had active programs in the geological sciences that would utilize the seismic station as an educational tool. The S102 seismometers are low-cost, vertical-component broadbands with excellent response to both local and teleseismic events. However, they have the disadvantage of thermal and moisture parameters that require them to be deployed in indoor facilities, which tend to be inherently "noisy." Most instruments of the Ohio Seismic Network are on ground floors of buildings, and a few are on isolated piers.

Currently, the network consists of 23 independently operated, volunteer stations (Figure 2). Several stations were established by universities, and one by a high school,



ACSO Alum Creek (Ohio Earthquake Information Center)
OGSO Ohio Geological Survey
ACEO Ashtabula EMA
BCSO Bloom-Carroll Schools
BHSO Botkins High School
BGSO Bowling Green State University
CSCO Clark State Community College
CLEO Cleveland Museum of Natural History
COWO College of Wooster
ECCO Edison Community College
KSUO Kent State University
LECO Lake Erie College
LCCO Lakeland Community College
MOSO Mohican Outdoor School
MUCO Mount Union College
OSLO Ohio State University–Lima
OSMO Ohio State University–Mansfield
OUAO Ohio University
SSUO Shawnee State University
UOCO University of Cincinnati
UTLO University of Toledo
WSCO Wright State University–Celina
WSDO Wright State University–Dayton
YSUO Youngstown State University

▲ **Figure 2.** Distribution of Ohio Seismic Network stations.



▲ **Figure 3.** Filtered seismogram from OhioSeis station CLEO at the Cleveland Museum of Natural History for the Ashtabula mainshock on 26 January 2001. CLEO is approximately 85 km from the epicenter.

with independent purchase of all necessary equipment. The Ohio Geological Survey provided only expertise in station installation.

Since 1999, the Ohio Seismic Network has recorded and located nine mainshocks within the state borders and one in southern Michigan, including a damaging m_{bLg} 4.5 event at Ashtabula, Ohio, on January 26, 2001 (Figure 3). This event was the largest of an ongoing (since 1987) sequence of earthquakes thought to have been induced by a nearby Class I injection well (Seeber and Armbruster, 1993; Nicholson and Wesson, 1990). The epicentral location of the 2001 mainshock and other data collected by the Ohio Seismic Network were instrumental in demonstrating that the pressure front of the injection fluid had moved 4.5 km south of the injection site and encountered a previously unknown seismogenic fault (Hansen *et al.*, 2001). The network has been able to determine precise locations for several felt events that were below the recognition level of regional stations. The network responds on a regular basis to numerous inquiries from citizens who thought they might have felt an earthquake and in several cases has been able to identify blasts at specific quarries as the source of the felt report .

In addition, the attention brought to local seismicity by the presence of the network and an extensive waveform database have spawned a variety of studies of seismic risk, crustal velocities, and basement structures. It was discovered that network instruments could track the ground-contact phase of a tornado (Vincent *et al.*, 2002). Thus, the Ohio Seismic Network has demonstrated that research-quality data acquisition and a broad educational mission can be carried out with a modest investment and very low annual operating costs.

REFERENCES

Hansen, M. C. (2000). OhioSeis—The Ohio seismic network, *Ohio Geology* **1**, 1, 3–7.

Hansen, M. C. (2000). *Earthquakes in Ohio*, Ohio Division of Geological Survey Educational Leaflet 9.

Hansen, M. C., G. E. Larsen, E. M. Swinford, and L. J. Ruff (2001). Seismic spotlight shines on Ashtabula, *Ohio Geology*, **3**, 1, 3–5.

Nicholson, Craig and R. L. Wesson (1990). Earthquake hazard associated with deep well injection: A report to the U.S. Environmental Protection Agency, U.S. Geological Survey Bulletin 1951, 74 pp.

Seeber, Leonardo and J. G. Armbruster (1993). Natural and induced seismicity in the Lake Erie-Lake Ontario region: Reactivation of ancient faults with little neotectonic displacement, *Géographie Physique et Quaternaire* **47**, 363–378.

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

Vincent, R. K., Z. Zeng, S. Ping, and Z. Shaofen (2002). Wavelet-packet transformation analysis of seismic signals recorded from a tornado in Ohio, *Bulletin of the Seismological Society of America* **92**, 2,352–2,368.

Ohio Geological Survey
4383 Fountain Square Drive
Columbus, OH 43224-1362
(M.C.H.)

Department of Geological Sciences
The University of Michigan
Ann Arbor, MI 48109-1063
(L.J.R.)

Reprinted from Seismological Research Letters, September/October 2003, Volume 74, No. 5, p. 561-564.