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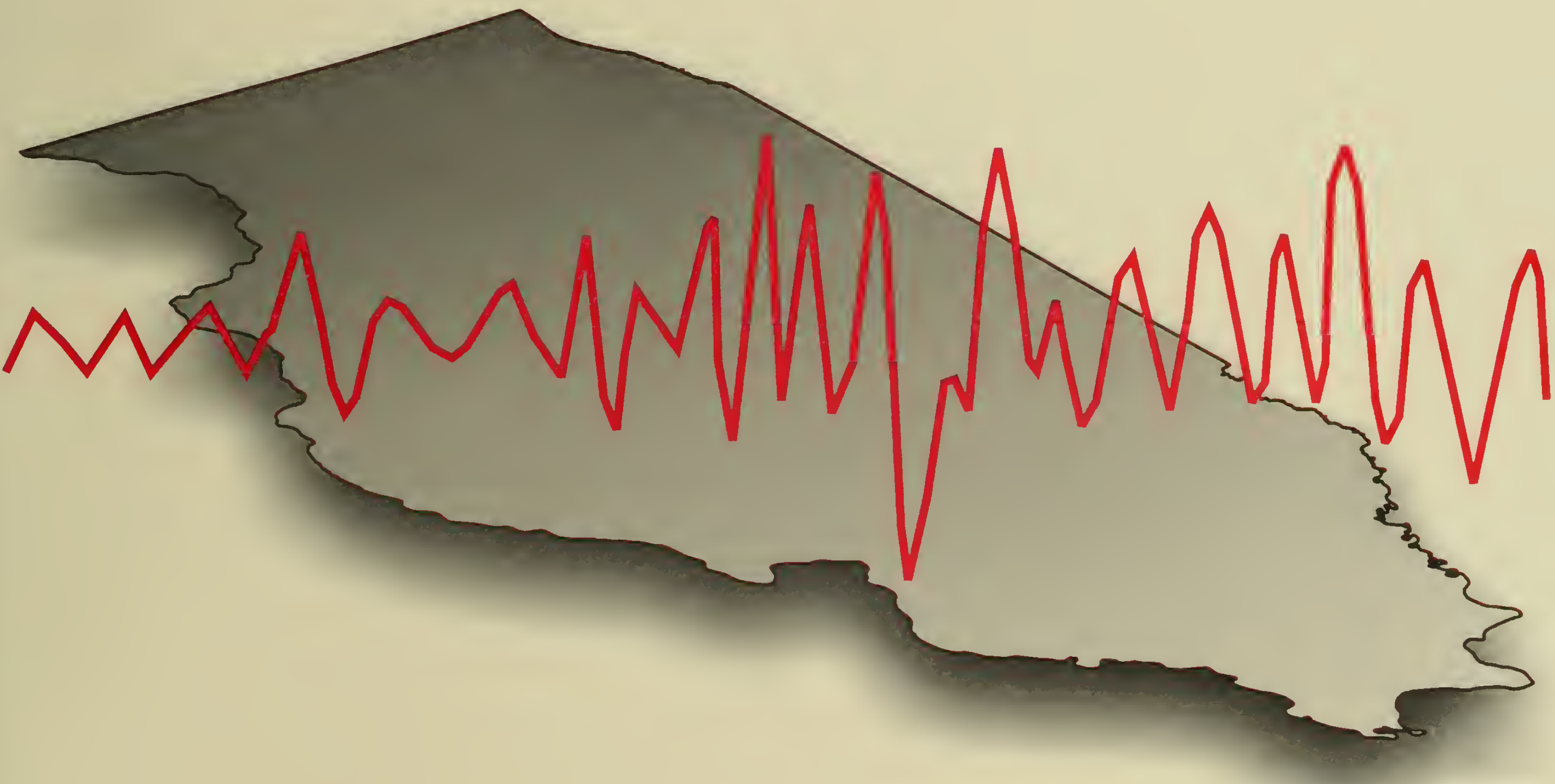
The Earthquake of September 2, 1999, in Northern Illinois:

Big Lessons from a Small Earthquake

Timothy H. Larson



Environmental Geology 153 2001

George H. Ryan, Governor

Department of Natural Resources
Brent Manning, Director

ILLINOIS STATE GEOLOGICAL SURVEY
William W. Shilts, Chief

ILLINOIS
DEPARTMENT OF NATURAL RESOURCES

ILLINOIS STATE GEOLOGICAL SURVEY
1905

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Abstract

A small earthquake, magnitude m_b 3.5, jolted northern Illinois at 11:17 A.M. CDT (16:17:29.7 UTC) on September 2, 1999. The epicenter was located near the village of Amboy, Lee County, at latitude 41.73°N and longitude 89.40°W and at an estimated depth of 5 km (3 mi). The earthquake was felt over an area of about 10,400 km^2 (4,000 mi^2), including parts of 11 counties in Illinois and the immediately adjacent regions of Wisconsin and eastern Iowa. Within two weeks of the event, two separate intensity surveys were initiated by the Illinois State Geological Survey and the U. S. Geological Survey to investigate the effects of this earthquake. Observed Modified Mercalli Intensity reached a maximum value of MMI V in two small locations west of the epicenter. An asymmetrical 1,000 km^2 (400 mi^2) area of MMI IV surrounded these locations. Local geology was an important factor in the intensity pattern. Earthquake intensity was greater in areas underlain by thick sand and gravel deposits, even those buried by subsequent glacial activity, than in areas underlain by thin glacial drift over bedrock.

Although small in magnitude, this earthquake is significant because it is the second instrumentally documented earthquake located on, or very near, the Peru Monocline. In 1972, a magnitude m_b 4.6 earthquake occurred about 16 km (10 mi) southeast of the 1999 earthquake. A focal mechanism solution from the 1972 earthquake is consistent with strike-slip movement parallel to the trend of the Peru Monocline. Although one earthquake epicenter near the Peru Monocline might be considered coincidental, the two epicenters, taken together, may suggest the possible reactivation of a Paleozoic structure within the North American midcontinent.

Two steps are recommended to increase the earthquake preparedness of northern Illinois:

1. Consider the effects of soil amplification of seismic waves when designing and retrofitting structures built on thick alluvium or glacial sediments in northern Illinois.
2. Investigate the possible link between these two earthquakes and the Peru Monocline and the implication for seismic hazard in this area.

Introduction

When a small earthquake rattled across northern Illinois just before lunch on Thursday September 2, 1999, the popular response was first surprise, then disbelief, followed by curiosity. Because earthquakes in this part of the world are rare events, the widely felt, single, sharp jolt from this earthquake generated considerable local interest. Given the novelty of the event and the images of devastation wrought by a major earthquake that occurred in Turkey less than a month before on August 17th, this curiosity is quite understandable. This earthquake is scientifically significant not because of its size, having a magnitude of only m_b 3.5, but because of its location and the subtle variations in the effects of the earthquake waves as they passed through the region. Lasting only a few short seconds, this minor earthquake left a record that can provide some important insights into present-day tectonic processes and future seismic risk in northern Illinois.

Although minuscule in comparison to contemporary catastrophic earthquakes in Taiwan (M_w 7.6) and Turkey (M_w 7.4), the September 1999 northern Illinois earthquake had sufficient energy to be detected by many seismological observatories in the Midwest (fig. 1). Instrumental readings from several locations were compared, and the earthquake's epicenter was plotted at a position about 6.5 km (4 mi) west of the village of Amboy (about 24 km [15 mi] south-southeast of Dixon) at latitude 41.731°N, longitude 89.398°W. Focal depth was estimated to be about 5 km (3 mi). The time of origin was fixed at 11:17 A.M. CDT, and the magnitude was measured at m_b 3.5 (information from National Earthquake Information Center, Boulder, Colorado). Unfortunately, the signals from this earthquake were too weak and the number of recording instruments too few to provide additional details on the source mechanism of the earthquake. However, because of the rarity of this event, these basic facts—location, origin time, and size—are valuable pieces of information that can lead to a better understanding of earthquakes in this area.

The popular notion that northern Illinois is immune to earthquakes is not completely true. Earthquakes in northern Illinois are rare but not unique events (fig. 2). The September 1999 earthquake epicenter is approximately 11 km (7 mi) north-northwest of the epicenter of an m_b 4.5 earthquake that occurred on September 15, 1972. Several other minor earthquakes have been reported in northern Illinois; all but one (Du Page County 1985) occurred before reliable seismological instrumentation was present in the area. The locations of these earlier earthquakes are not known very well. Reports of how strongly the earthquakes were felt at various locations are the only records of the event. Trying to determine the point of origin from these reports can be problematic. For instance, the largest earthquake reported in northern Illinois, with an estimated magnitude greater than 5, occurred in 1909. It caused widespread, although minor, damage particularly in the Fox River valley from Joliet to Elgin. Even after reviewing dozens of newspaper reports, Udden, who actually experienced the event, was not able to establish a point of origin (Udden 1910). Figure 2 shows this earthquake in eastern Ogle County, but other maps have shown it as far away as northeastern Winnebago County (Heigold and Larson 1990) and northern Will County (Stover and Coffman 1993).

Based on past earthquakes, risk from earthquake damage in northern Illinois is low, but not zero. Frankel et al. (1996) calculated the probable maximum earthquake-related ground vibrations that might occur over a 50-year period. They estimated that there is a 2% chance that slightly damaging vibrations (horizontal accelerations exceeding 8% of gravity) might occur sometime within

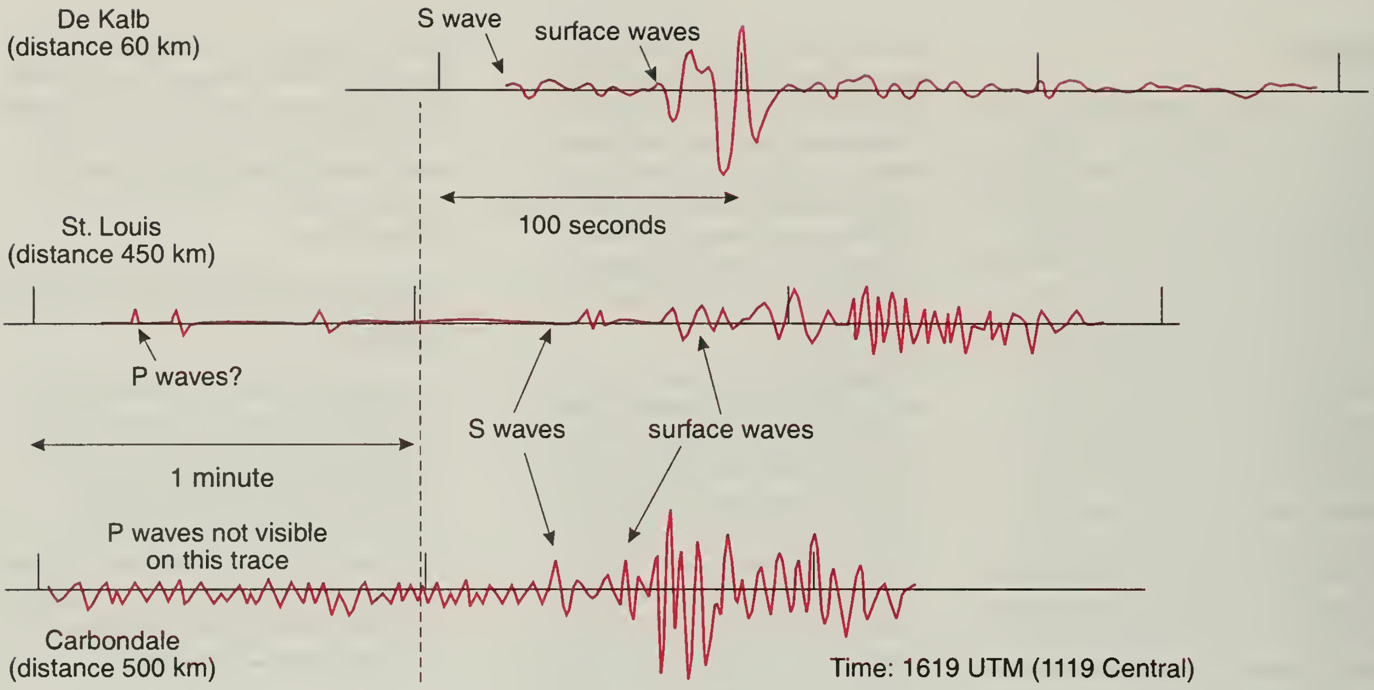


Figure 1 Simplified waveforms of the September 2, 1999, earthquake recorded at De Kalb, Illinois, St. Louis, Missouri, and Carbondale, Illinois. The De Kalb waveform (top) was redrawn from a seismograph recorded at Northern Illinois University. The horizontal axis for this waveform is graduated in 100-second time units. The St. Louis waveform (center) was redrawn from the daily seismograph recorded at St. Louis University and obtained from their Web site. This is a vertical-component record. The Carbondale waveform (bottom) was redrawn from the daily seismograph recorded at Southern Illinois University and obtained from the St. Louis University Web site. This is a horizontal-component record. The St. Louis and Carbondale records are shown at approximately the same scale with 1-minute time units correlated to the Universal Time Standard (UTC). Surface waves accounted for most of the vibrations recorded at all three sites. The onset of the S wave is obscured by instrument noise on the De Kalb record. Possible P wave arrivals lead the S wave arrival on the St. Louis record by about a minute. P wave arrivals are not visible on the Carbondale record.

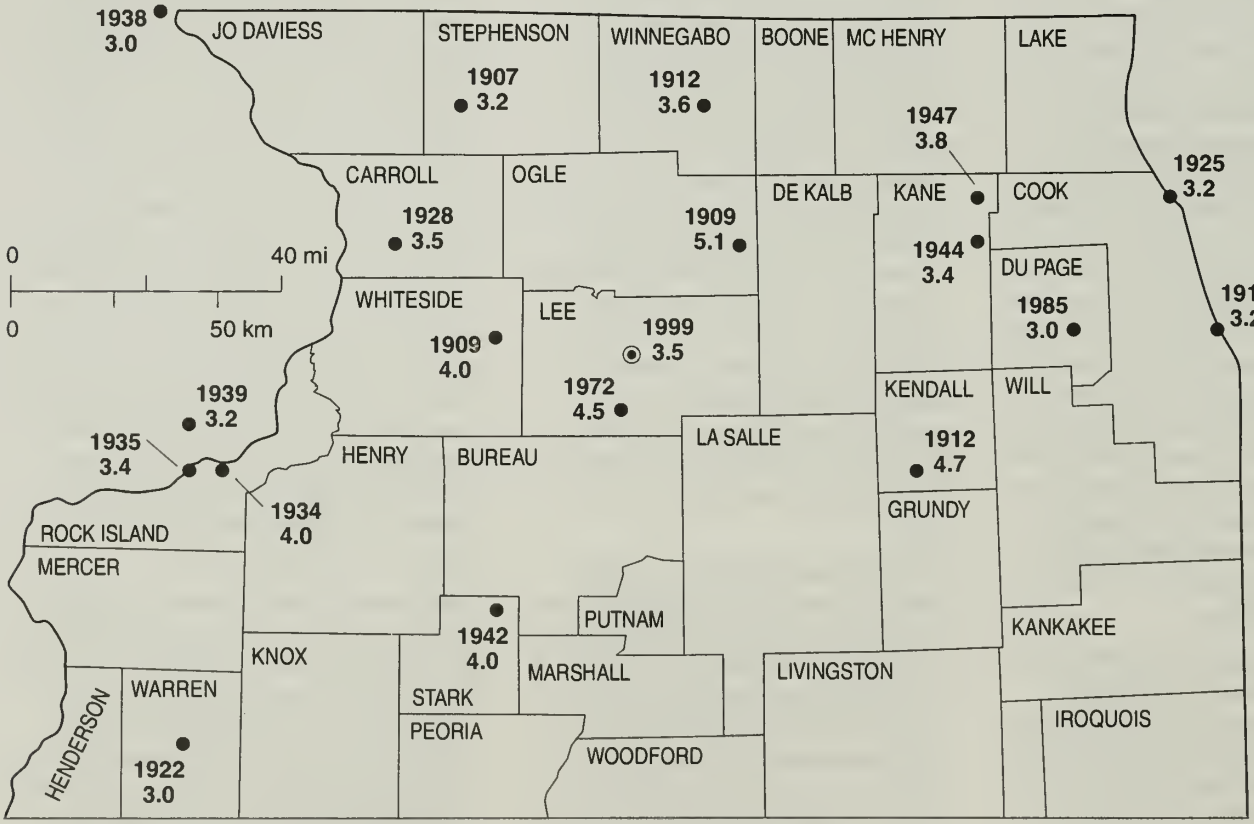


Figure 2 Northern Illinois earthquakes with year of occurrence and magnitude. Data are from St. Louis University Earthquake Center.

that period at Rockford, Dixon, or Sterling. In this calculation, they assumed that no earthquake in northern Illinois would exceed M_w 6.5. This is only slightly more conservative than the m_b 6.1 maximum earthquake estimated by Nuttli and Herrmann (1978). Although the probability of such an earthquake occurring is low (recurrence interval estimated by Nuttli and Herrmann [1978] at 1,000 years), it would be strong enough to cause moderate damage in the epicentral region.

Local Geology and Its Influence on Earthquakes

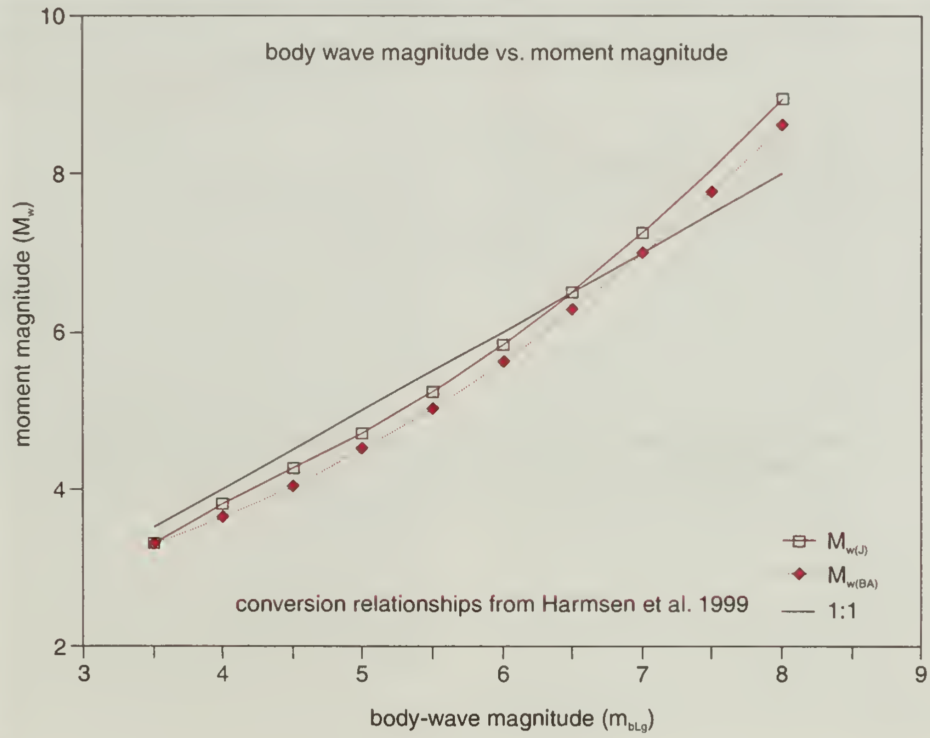
Geologic Structures There are few geologic structures in northern Illinois that could cause earthquakes (fig. 3), and, as yet, no earthquakes have been conclusively linked to any of them (Nelson 1995). In fact, earthquakes in continental interiors around the world are rare and difficult to explain (Johnston 1989). One likely explanation for earthquakes in the central United States is that they occur at weak zones in the rigid lithosphere (fig. 4) as it is being pushed across the asthenosphere of the earth (Zoback and Zoback 1981, Carlson et al. 1983). Ancient folds or faults, formed in the lithospheric plate by ancient stresses, are now zones of weakness in the crust that are more prone to fracturing than are other locations. In order for fracturing to occur, the old structures must be aligned so that the predominant northeast-southwest trend of the modern stress field cuts across them. East-west-trending structures, such as the Plum River Fault Zone in northern Illinois (fig. 3), are not known to be active in the modern Central North American stress field (Zoback and Zoback 1981). Structures aligned either northwest-southeast, northeast-southwest, or even north-south are more likely to spawn earthquakes in Illinois. Of these favorably oriented structures, the Sandwich Fault Zone is the most prominent in terms of extent, but the Peru Monocline may have greater vertical displacement (see Nelson 1995 for summary and bibliography).

The Peru Monocline (fig. 3) is a 100 km (65 mi) long, northwest-southeastward-trending fold belt in which the rocks dip steeply to the southwest into the

Earthquake Magnitude: How Big Was It?

The size of an earthquake is normally reported as a value called *magnitude*, which is determined by taking the common logarithm of the largest ground motion recorded during the arrival of a particular type of seismic wave and applying a standard correction for distance to the epicenter. Earthquake magnitudes are generally called *Richter magnitudes* for the seismologist who first used the measurement. However, there are many variations depending on the type of seismic wave being measured. The original Richter magnitude (also called the local magnitude, M_L) did not specify a particular type of seismic wave and is not used very much anymore. More frequently, magnitudes are based on P body waves (m_b), and surface waves (M_S) (Bolt 1993). In the central United States, a hybrid-type of magnitude using short-period surface waves (m_{bLg}) is in common usage. Because the frequency content of these waves is more like body waves than usual long-period surface waves, this magnitude has always been classified as a type of body wave magnitude (Nuttli 1973). Unless otherwise noted, this type of magnitude is used in this report.

In recent years, a new type of magnitude has been defined that attempts to relate the size of the earthquake to the seismic moment or energy released by the quake. The moment magnitude (M or M_w) takes into account the size of the fault that ruptured and the amount of movement on the fault (Bolt 1993). Neither of these two parameters is normally observable for the small to moderate earthquakes common in the central United States, so formulas are needed to convert the observed m_{bLg} values to M_w values. Two conversions are illustrated using formulas given by Boore and Atkinson (1987) ($M_{w(BA)}$) and Johnston (1996) ($M_{w(J)}$) as reported by Harmsen et al. (1999). The observed m_{bLg} value is slightly greater than M_w for small to moderate earthquakes but is much less than M_w for large earthquakes.



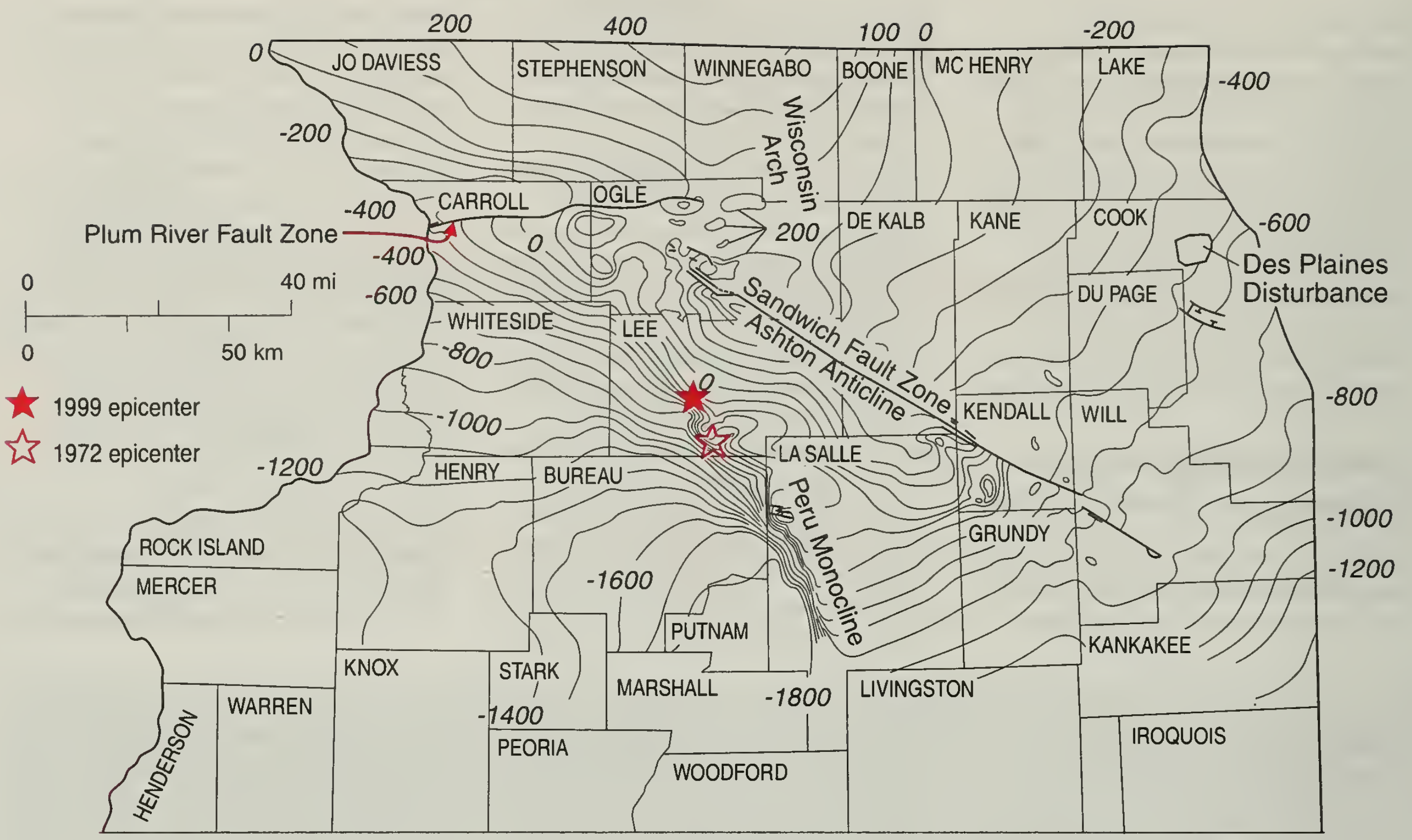


Figure 3 Structure map drawn on the top of the Franconia Formation (Nelson 1995) with epicenters of 1999 and 1972 earthquakes. Elevations are given in feet.

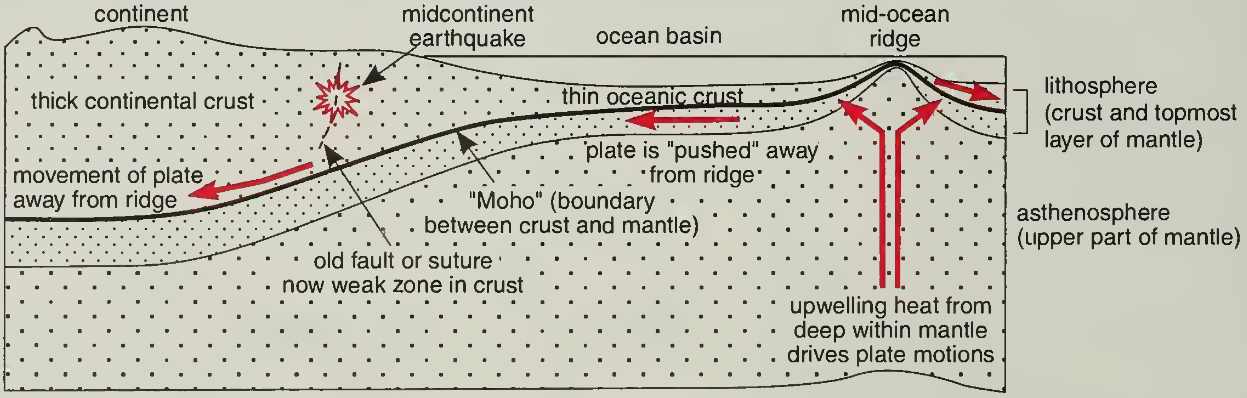


Figure 4 Diagrammatic west to east cross section through the North American Plate. The continental plate is pushed westward by the pressure from upwelling magma along the mid-Atlantic ridge. The rigid plate formed from the crust and topmost layer of the mantle slides along the top of the mantle. Earthquakes sometimes occur within the interior of the plate when stress builds at weak zones caused by old faults.

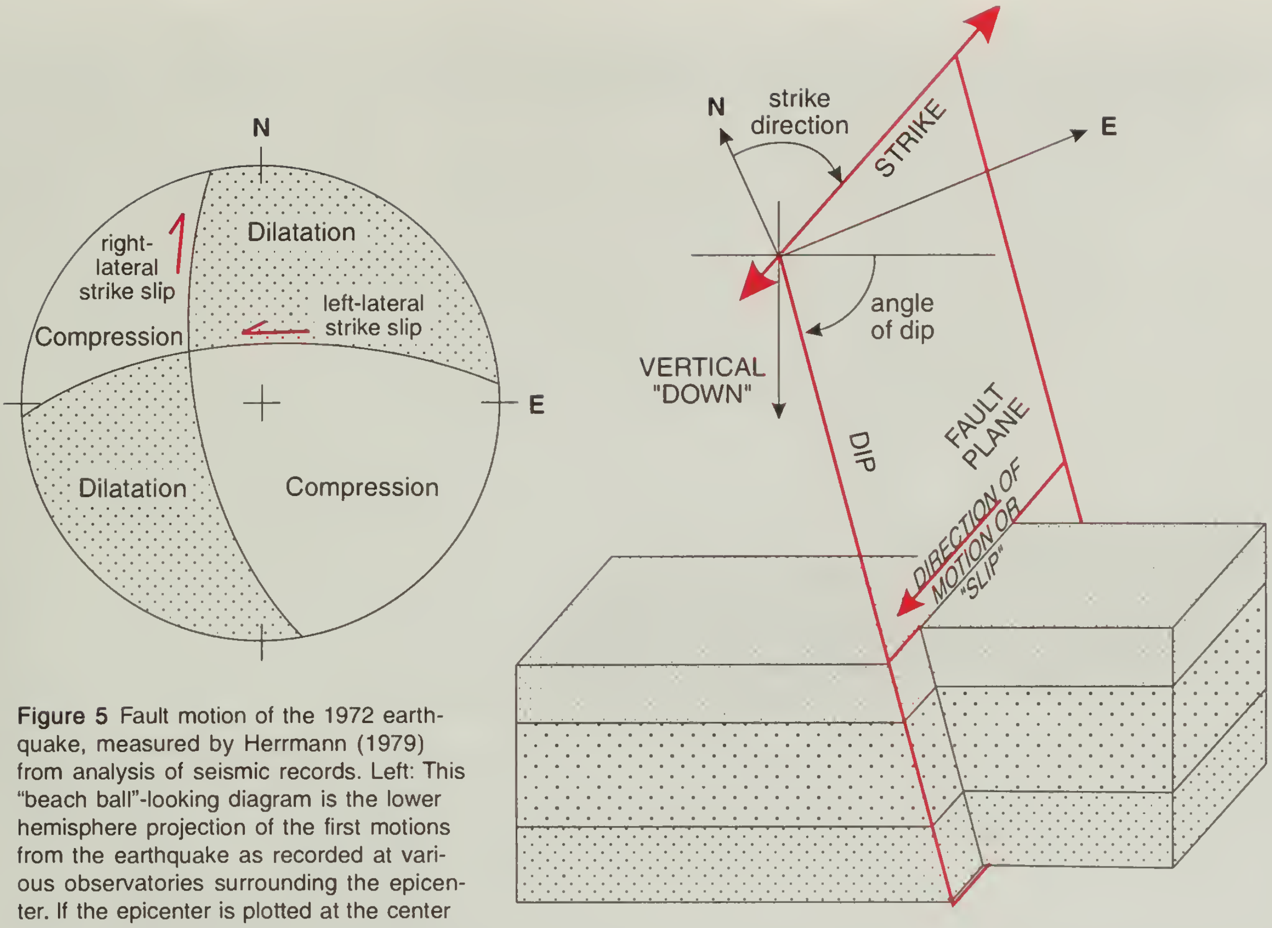


Figure 5 Fault motion of the 1972 earthquake, measured by Herrmann (1979) from analysis of seismic records. Left: This "beach ball"-looking diagram is the lower hemisphere projection of the first motions from the earthquake as recorded at various observatories surrounding the epicenter. If the epicenter is plotted at the center of the hemisphere, then the observatory locations are plotted as points at different directions and distances from the center. Depending on which quadrant the observer is in relative to the earthquake epicenter, the first motion is sensed as either *compression* (pushing toward the observer) or *dilatation* (pulling away from the observer). Quadrants that experienced dilatation are shaded. The *strike* of the fault plane (direction of the line of the fault plane if it were projected up to the earth's surface) is along the boundaries of the quadrants. Unfortunately, this type of analysis provides two possible strike directions, in this case, either a little west of north or a little north of east. Because the point where the quadrants meet is offset from the center of the hemisphere, we know that the fault is dipping steeply to the north or west. The sense of the motion or *slip* is *lateral* (sideways) along the direction of the fault with little up or down motion. The motion is toward the compressional quadrants, so for the north-south strike plane the motion is *right-lateral* (toward the right when facing west) and for the east-west strike plane the motion is *left-lateral* (toward the left when facing north). Right: A block diagram illustrating a *high-angle strike-slip* fault with a northeast *strike* direction and *left-lateral* motion.

Illinois Basin (Nelson 1995). The structure is most prominent in La Salle County where the relief on the southwest limb is as much as 500 m (1,600 ft). In some area coal mines, the coal beds dip 45° on the steep flank of the monocline (Nelson 1995). The Peru Monocline is less pronounced to the northwest where the relief decreases and the dip becomes very gentle as the structure merges with the Ashton Anticline.

Within the precision of the seismographic data, both the 1999 and 1972 earthquakes were located within the earth's crust 5 and 13 km (3 and 8 mi) below the Peru Monocline. The fault displacement indicated by an analysis of seismograms from the 1972 earthquake (fig. 5) is high-angle strike-slip either right-lateral to the north-northwest or left-lateral to the east-northeast (Herrmann 1979). In analyzing the 1972 earthquake, Heigold (1972) noted the proximity of the epicenter of that earthquake to the Peru Monocline (fig. 3) and suggested that the earthquake was the result of faulting within the crust related to a zone of weakness near the region where the Peru Monocline merges with the Ashton Anticline. This interpretation is consistent with the north-northwest plane of Herrmann's analysis of the seismic records. The occurrence of a second earthquake in the same area reinforces Heigold's concept.

A third earthquake, which occurred early in the morning of May 27, 1881, also might be related to the Peru Monocline. Very little is known about this earlier earthquake except that it caused minor damage in La Salle, especially at the glass and bottle factories (Stover and Coffman 1993). Because La Salle sits directly on the Peru Monocline, these damage reports imply that the earthquake epicenter was beneath the monocline. However, without modern seismograph recordings, we can only estimate the approximate location and magnitude of this older earthquake. The damaged factories were built on the flood plain of the Illinois River, which could have amplified ground motions. The actual earth-

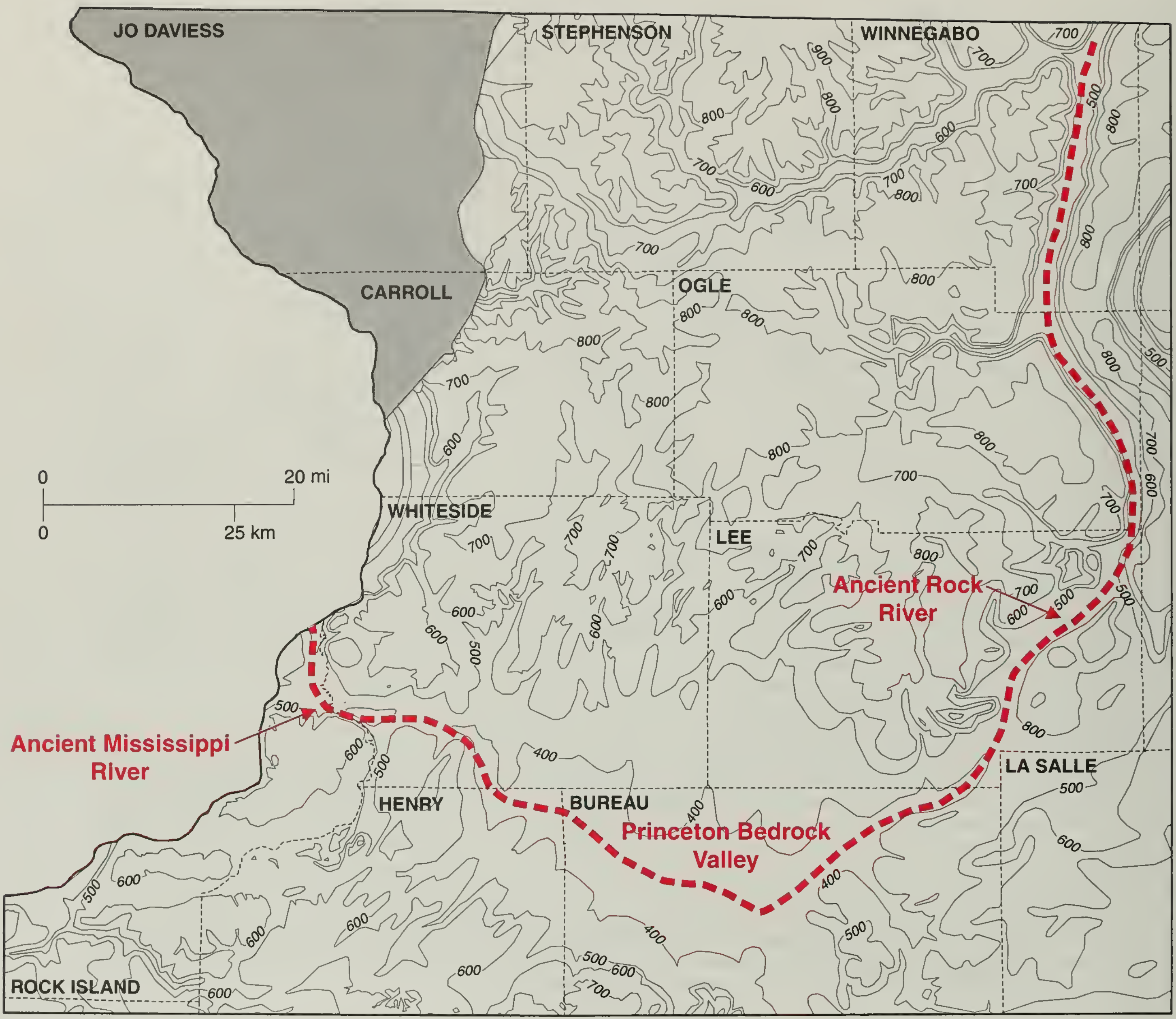


Figure 6 Buried bedrock topography (Herzog et al. 1994). Contours in feet above MSL. The ancient Mississippi and Rock Rivers followed different courses than they do today.

quake epicenter might have been a considerable distance from the site of the most severe damage. Nevertheless, the available observations place this earthquake in the vicinity of the Peru Monocline and provide further evidence of modern earthquake activity near this structure.

Effects of Soils Local geology not only influences the cause and location of earthquakes, it also controls the amplitude of the ground shaking. In northwestern Illinois, sedimentary rocks, primarily limestone and dolomite, lie exposed or within 25 ft of the ground surface beneath most of the area (Piskin and Bergstrom 1975). These generally flat-lying rocks were dissected by several river systems prior to glaciation. Some of these rivers are still active today, but others flowed in valleys that were filled and buried by glacial activity (Horberg 1950). Both the modern Rock and Mississippi Rivers flow, at least in part, within relatively new channels. A long reach of the ancient Mississippi channel, known as the Princeton Bedrock Valley (fig. 6), lies buried 100 to 400 ft beneath western Bureau and southern Whiteside Counties (Horberg 1950, Larson et al. 1995). The ancient Rock River followed a southerly course into what is now the Illinois River. The old channel has been completely buried (Horberg 1950, Herzog et al. 1994). This general geologic setting of thinly covered bedrock areas interspersed with deeply eroded valleys filled with glacial outwash, lake sediments, and tills can have an important influence on the way earthquake waves are transmitted and felt at the ground surface.

Often, earthquake damage occurs in what appears to be isolated or random locations, but on closer examination, it

Modified Mercalli Intensity Scale

Intensity Level	Description of Effects
I	**Not felt.** Rare reports of doors slowly swinging. Rare reports of slight swaying of trees and bodies of water.
II	**Felt indoors by few**, especially those on upper floors, seated or lying down. Hanging objects may swing, especially if delicately suspended. Some birds, animals reported to be uneasy or disturbed.
III	**Commonly felt indoors,** particularly by those seated or lying down, although often not recognized immediately as an earthquake. Frequent reports of swaying or swinging objects. **Vibrations similar to the passing of light or lightly loaded trucks**. May hear slight rattle or creaking. Duration may be estimated in some cases.
IV	**Felt indoors by almost all; felt outdoors by some.** Frightens some, particularly those not accustomed to earthquakes. Hanging objects often swing. **Distinctive rattling of dishes, glassware, windows, and doors** and creaking of walls frequently noted by those indoors, but nothing is knocked over or falls from shelves. Vibration like that resulting from the passing of heavy trucks, or **sensation of a jolt like a heavy object striking the building or falling of heavy objects inside**. Liquids in open vessels such as aquariums and toilet bowls disturbed slightly but do not spill. Standing cars rock noticeably. Average peak velocity 0.2–0.8 inches/second.
V	Felt indoors by all; felt outdoors by most. **Frightens many**; some run outdoors or seek cover. Some report difficulty in moving or standing. Frequent reports of buildings trembling/groaning and swinging objects, moving doors and shutters. **A few items knocked over or fall from shelves** and some objects displaced; occasional broken glassware and crockery but not generally. **Rare reports of cracked windows and cracked plaster.** Trees and bushes shaken slightly but fruit and limb fall from trees very rare. Average peak velocity 0.8–2 inches/second.
VI	Felt by all; **frightens most or all**. Furniture moved. Objects upset. **Many report some glassware and crockery broken. Damage to some chimneys**. Trees and bushes shake moderately to strongly. Occasional rock falls. Average peak velocity 2–3 inches/second.
VII	**Everyone runs outdoors.** Felt in moving cars. Some people fall. Weak chimneys broken at roof. **Fall of plaster, loose bricks, etc.** Rock falls common; ground cracks may be observed. Average peak velocity 3–5 inches/second.
VIII	**Frightens all; many panic; all report difficulty in standing.** Major damage to unreinforced masonry. Most chimneys fall. Virtually all cabinet doors thrown open and items ejected. Average peak velocity 8–12 inches/second.
IX	**Panic is general.** Total destruction of weak structures. **Considerable damage to well-built structures.** Underground pipes may break. Ground cracks conspicuously. Average peak velocity 18–22 inches/second.
X	Panic is general. Well-built wooden structures and bridges are severely damaged, and some collapse. **Most masonry structures destroyed.** Railroad tracks bend slightly. Cracking and failure in wet ground ubiquitous. Water slopped over banks. Average peak velocity more than 24 inches/second.
XI	Panic is general. **Few buildings survive. Railroad rails bend greatly.** Broad fissures in ground.
XII	Panic is general. **Total destruction.** Objects thrown upward into the air.

becomes clear that the damage pattern follows variations in local geology. Two examples are the catastrophic damage to Mexico City in 1985 (m_b 7.9) and the collapse of portions of the San Francisco-Oakland Bridge in 1989 (m_b 7.0) (Bolt 1993). In both cases, the earthquakes originated far away, and towns between the epicenter and the damaged area were not as strongly shaken. The severely damaged structures had been built on soft soils that shook much more intensely than nearby sites where bedrock was near the surface. The amplitudes of earthquake waves increase as they pass from rock into softer sediment such as sand or mud. The effect is greatest for thick, soft, water-saturated soils (Tinsley and Fumal 1985, Seale and Archuleta 1989, Borcherdt and Glassmoyer 1994). Although earth materials behave somewhat differently during small and large earthquakes, this small northern Illinois earthquake provided an opportunity to estimate the relative amplification of local soils. Unlike southern California or Mexico City, there were no operating strong motion detectors in northern Illinois on September 2, 1999. Therefore, indirect means were used to measure the relative strength of ground shaking by documenting the effects the shaking had on people and buildings.

Intensity: Documenting the Effects of the Earthquake

The effects of an earthquake, which include people's perceptions and responses to its motion and observed damage to objects and buildings, can be systematically studied and categorized. Variations in these effects from place to place are due to changes in the intensity of the earthquake waves. Earthquake intensity differs from earthquake magnitude, a measure of the size or total energy released from the earthquake, which has a unique value for each earthquake. In general, intensity decreases with increased distance from the epicenter, but, in detail, intensity patterns are strongly influenced by the mechanism of the earthquake faulting (the source) and by variations in soil composition and thickness at the observation point (the site). The severity of the damage to manmade structures depends as much, or more, on their design and construction as on the strength and duration of the ground motions.

The Modified Mercalli Intensity (MMI) scale (Wood and Neumann 1931) has become the standard scale for measuring and reporting earthquake intensity in the United States (see sidebar). The scale uses Roman numerals I through XII to indicate variations in intensity from "not felt" to "total destruction." Roman numerals are used to emphasize the wide range of effects encompassed by each level and to preclude the use of misleadingly precise decimal values. Wood and Neumann's original classification has stood the test of time amazingly well. Only a few minor changes have been suggested since 1931 to account for newer construction practices and to allow comparisons of damage to engineering seismograph measurements from instruments within the damaged buildings (Stover and Coffman 1993, Dengler and Dewey 1998). In general, at the lower levels (I through V), there is no damage, only an increasing awareness of the shaking, but the higher levels (VI through XII) are distinguished by increasing degrees of damage to buildings. For large earthquakes, intensity is easily quantified by casualty figures and damage reports. For small earthquakes that cause little or no damage, intensity is very difficult to quantify because it depends on reports of human perceptions of the event. Many observations are needed to ensure the reliability of the measurement.

Even though initial reports suggested that the 1999 earthquake caused almost no damage, the intensity pattern can still provide valuable insights for earthquake hazard planning. Because enhanced ground motion should occur at more or less the same sites from any earthquake, we can learn which areas are more susceptible to damage from small or large earthquakes. For this report, two independent surveys of the effects of the September 2nd earthquake have been combined. The Illinois State Geological Survey (ISGS) conducted one survey, and the U.S. Geological Survey (USGS) used a slightly different method to conduct the second survey. The combined results are more comprehensive than either study individually.

The ISGS Intensity Survey Capitalizing on the unusual local attention to earthquakes in September 1999, the ISGS conducted an informal intensity survey of the area and enlisted the assistance of several local newspapers to help reach survey participants. Already interested in the event, editors of the *Rockford Register Star, Freeport Journal Standard, Rochelle News Leader, Dixon Telegraph*, and *Fulton Press* readily agreed to publish a survey questionnaire in their papers (Appendix 1). By September 14th, these newspapers, which serve populations from one end to the other of the area that felt the earthquake, had published a short questionnaire provided by the ISGS, asking readers to recount their experience of the earthquake. In addition, the Dixon paper posted a version on their Web site for a week. Questionnaires were also distributed to participants at a geologic field trip that was held in the Rockford area on September 11, 1999. Questions on the survey focused on eliciting the exact location of the observer and precisely what earthquake effects were observed.

A total of 535 questionnaires were returned to the ISGS either by mail or e-mail. Respondents were concentrated in Rockford (181 responses) and Dixon (112), but at least two responses came from 42 different communities in the region, and at least one response was received from 61 communities. An MMI value was assigned to each response. Responses were then grouped by location, and a value was assigned to each community (Appendix 2). Because there was virtually no damage from this earthquake, the community intensity primarily describes whether the earthquake was felt by only a few, by many, or by most people.

Relatively low levels of ground shaking were reported. Two reports of very minor damage came from Dixon, one from Freeport, and three from Rockford (fig. 7). One respondent felt the vibrations while in a moving automobile. Otherwise, most people experienced a single, loud jolt that rattled windows

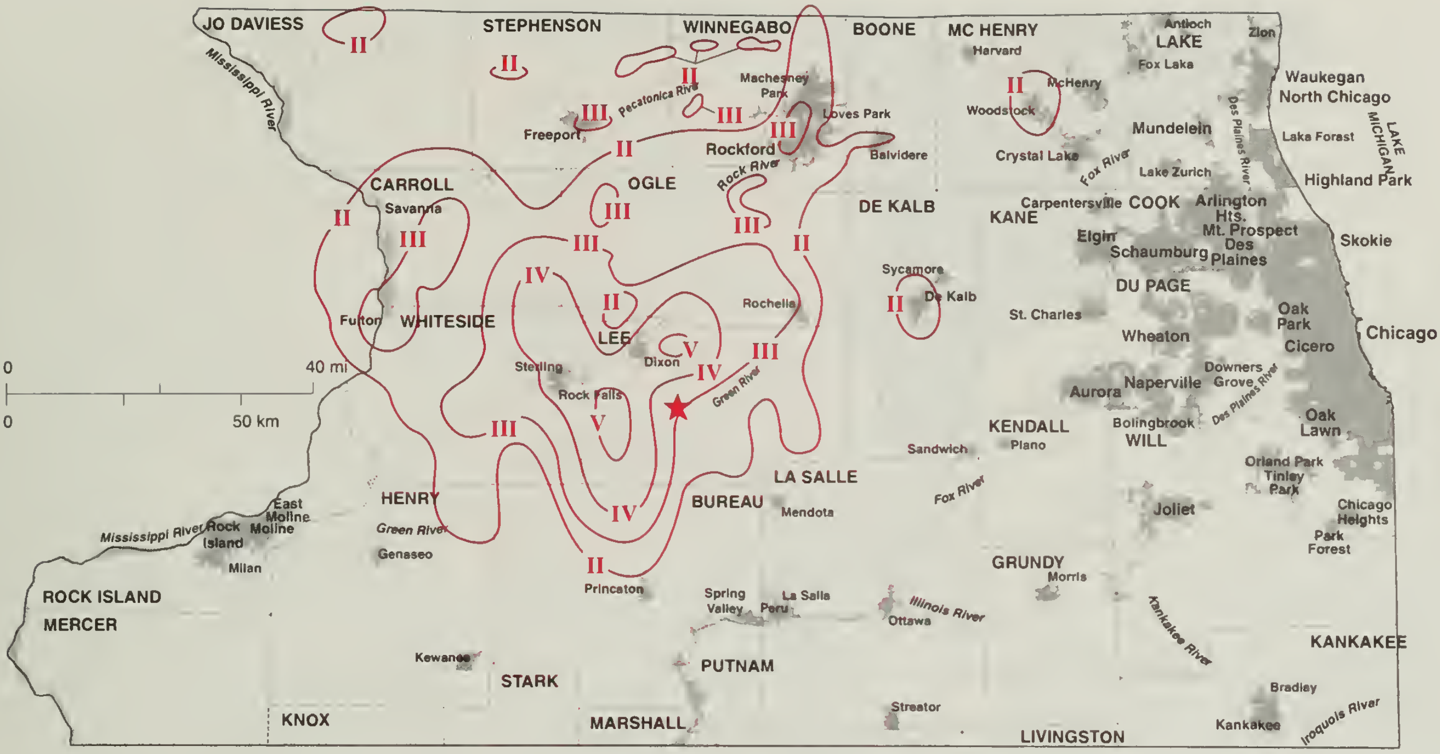


Figure 7 Isoseismal map of the September 2, 1999, earthquake. Values are drawn from combined and modified USGS and ISGS intensity data.

and dishes for a few seconds. No windows were broken, and only a few instances of objects falling from shelves were reported. The sensation of something striking or falling in the building was common. A few military veterans likened the sound to distant artillery or bomb blasts. Although dozens of people admitted to going outside after the earthquake, most did so out of curiosity and not fear.

Few people recognized the vibrations as an earthquake, partly because of the short, mild shaking and partly because of the rarity of the event in Illinois. Most people do not expect earthquakes to occur in Illinois so they do not consider earthquakes to be the likely cause of ground shaking. Instead, respondents initially attributed the shaking to a quarry blast (which is very common throughout northern Illinois), a sonic boom, or possibly a car or train accident. Even those who had experienced earthquakes in California initially refused to acknowledge that similar vibrations could be caused by an earthquake in Illinois. Only after learning of the widespread nature of the shaking from telephone conversations with friends or relatives or confirmation of the earthquake by the authorities did most people accept that the vibrations were caused by an earthquake.

The USGS Intensity Survey

Meanwhile, the USGS conducted an independent intensity survey of this earthquake using a direct mail postal card questionnaire sent to U.S. postmasters in towns within a radius of about 150 km (100 mi) from the epicenter. A total of 236 cards were returned from this survey (Hopper 1999, personal communication; Appendix 3). The USGS questionnaires, which were more detailed than the ISGS questionnaires published in the newspapers, asked the postmaster to summarize the effects of the earthquake in his or her community as well as to provide individual perceptions of the earthquake. The MMI values were then assigned to each community following a standard routine developed over many years at the USGS (Stover and Coffman 1993).

Combining Both Surveys When used together, these two surveys provide an excellent record of the intensity of this small earthquake. The USGS survey covers a wider area with more uniform density of observations than the ISGS survey, but the ISGS survey compiles individual responses of minor effects that might not have been noticed in the postmaster reports. It also documents effects from towns and rural areas that were not reported in the USGS survey. Particularly within the Dixon area, near the epicenter, the ISGS survey was able to differentiate intensities in several small communities served by the regional post office.

For this report, the more broadly based USGS survey was used as a starting point, augmented by more specific information in the ISGS survey. At many localities, the intensities assigned by the two methods were in agreement. Where they differed, a somewhat subjective method was used to determine the most likely community intensity. Usually, the USGS intensity value was kept unless there was significant reason to change the value by one, or occasionally two, MMI units. At a few locations, the ISGS survey provided strong evidence to decrease the assigned intensity. The most significant discrepancies occurred in the northern extremes of the area in which the earthquake was felt, especially in

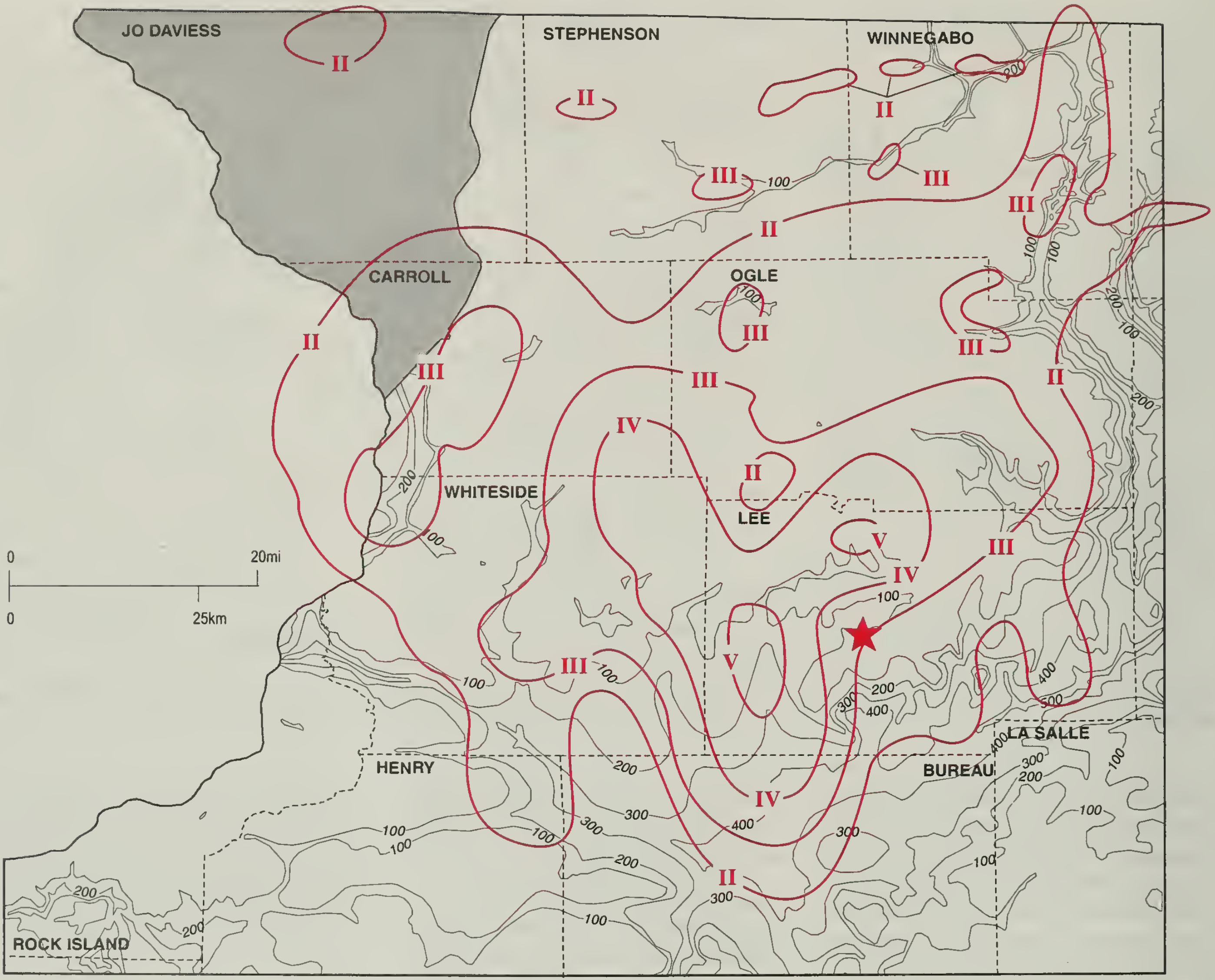


Figure 8 Isoseismal map of the September 2, 1999, earthquake overlain on a map of soil thickness (Piskin and Bergstrom 1975). Thickness contours are in feet.

Stephenson and Winnebago Counties. With the exception of Rockford, which was assigned MMI II, the USGS survey concluded that the earthquake was not felt in these two counties. However, the ISGS received many reports of the earthquake being felt throughout these counties.

Survey Results The greatest intensity reported in this survey (fig. 7) reached MMI V in Harmon, about 8 km (5 mi) west of the epicenter, and Nachusa, about 8 km north of the epicenter. These two small areas of MMI V were surrounded and linked by a larger area of MMI IV. The larger, western lobe of this MMI IV area stretches from Milledgeville in the north to Walnut and Ohio in the south. The eastern lobe extends along the Rock River from the Sterling-Rock Falls area east to Grand Detour and Lost Nation. The earthquake was generally felt over most of Lee and eastern Whiteside Counties and by many, but not all people, in Carroll, Ogle, northernmost Henry and Bureau, and western Whiteside Counties. Reports of MMI II to IV effects came from scattered locations throughout Stephenson and Winnebago Counties. Rare reports of individuals noticing earthquake effects were received from beyond this region.

The intensity pattern from an earthquake would intuitively be expected to form a set of concentric rings or a bull's-eye pattern around the epicenter. Instead, for this earthquake, the intensity pattern is elongate in the northeast-southwest direction, and the center is offset to the northwest from the epicenter (fig. 7). No MMI IV or V effects were reported for any community southeast of the epicenter. The earthquake was not felt at all in northwestern La Salle County only 25 km (15 mi) south of the epicenter, but it was felt distinctly in the Rockford area 65 km (40 mi) northeast of the epicenter and in the Fulton area 65 km (40 mi) northwest of the epicenter.

Much of the asymmetry in the intensity pattern may have been due to local effects from differences in soil type and thickness. These effects can be seen in figure 8, where the intensity contours from figure 7 have been plot-

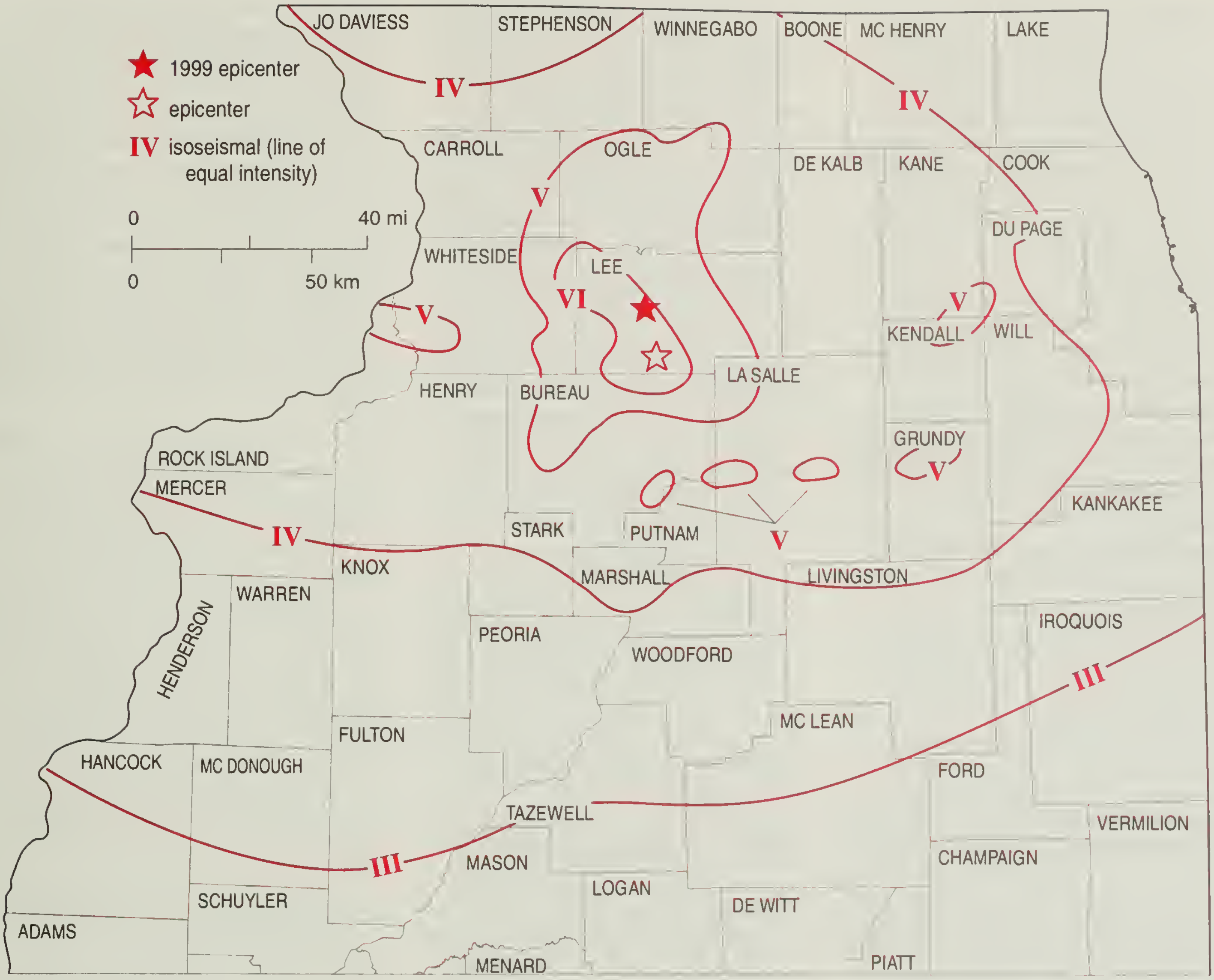


Figure 9 Isoseismal map of the1972 earthquake (Heigold 1972) with the1999 epicenter included.

ted on a map of the thickness of the soil (all unlithified sediments) overlying bedrock. One would expect higher intensities in areas with thicker soil, especially where this soil is composed of soft, water-saturated sediments, and, in many places, this correspondence holds true. For instance, the southwestern part of the MMI IV area lies over a northern tributary of the buried Princeton Bedrock Valley. Bedrock in this area is 35 to 130 m (100 to 400 ft) deep. Similar amplification could be the cause of increased intensities at locations overlying buried or partially buried reaches of the ancient Rock Bedrock Valley at Cherry Valley, Stillman Valley, Chana, and Rochelle to the east. Unusually high intensities reported in Stephenson and Winnebago Counties could also be attributed to soil amplification in the Pecatonica and Sugar River valleys. Higher intensities were reported in the vicinity of Fulton and Mt. Carroll, both of which are built at least in part on modern river sediments. Amboy, however, is built in an area of very shallow bedrock, which may be at least partly the cause of the relatively low intensities reported there.

Heigold (1972) conducted a similar intensity study following the somewhat stronger 1972 earthquake (fig. 9). That earthquake produced larger intensities, up to MMI VI, with minor damage reported in western Lee County (Heigold 1972, Stover and Coffman 1993). Although not identical, the geometry of the MMI V and MMI VI areas from the 1972 earthquake is very similar to the pattern of the MMI III and MMI IV areas from the 1999 earthquake. For both earthquakes, stronger ground shaking occurred north of the epicenter. The consistency of the intensity distribution pattern from these two different earthquakes is striking. It is reasonable to expect that two closely located earthquakes would have similar intensity distributions if they were caused by faulting having similar geometry. Although we have no direct measurements of the geometry of the 1999 faulting, the intensity pattern suggests that it may be similar to the north-northwest–trending right-lateral strike-slip determined by Herrmann (1979) following the 1972 earthquake.

Analysis of intensity patterns from both the 1999 and 1972 earthquakes shows greater intensities along river valleys. Heigold (1972) found small pockets of stronger ground shaking (MMI V) within areas characterized by generally weaker (MMI IV) vibrations. Outliers occur along the Illinois, Fox, and Mississippi River valleys (fig. 9) in areas underlain by thick soils. Higher intensity areas are similar to, but at a higher level than, the higher intensities reported in the Rockford, Freeport, and Fulton areas in 1999. These are all examples of the soil amplification effect. Bridges, buildings, and other structures built on thick soils in river valleys are at risk of greater earthquake ground motion than those built nearby on thin soil or bedrock.

Several other minor earthquakes have been reported in northwestern Illinois, all of which occurred before the advent of reliable seismological instrumentation (fig. 2). Those earthquakes were located based on intensity data, either by centering them near the locus of maximum intensity or at the center of the area of perception. We now know from the two instrumentally located earthquakes that the areas of maximum intensity and the centroid of the area of perception can be quite far from the true epicenter. Relocation of the 1909 Whiteside County, 1928 Carroll County, and 1907 Stephenson County earthquakes to the southeast would place them much closer to the 1972 and 1999 earthquake pair. Although this relocation is only speculative, it implies that the seismic activity in northwestern Illinois might be concentrated in a much smaller area than previously realized. This supposition could be verified by installing a network of sensitive seismometers to monitor more frequent, very small earthquakes. If a more concentrated area of seismicity were verified by such testing, it would suggest a need to reevaluate the seismic hazard in the area.

Conclusions

Much knowledge can be gained from what at first appears to be a small, inconsequential earthquake. In a part of the continent not known for earthquakes, two earthquakes have now been documented with very similar epicenters and intensity patterns. This pattern could be no more than happenstance, but the coincidence is quite remarkable. Not only were the two earthquakes in nearly the same location, but both also appear to originate beneath the same geologic structure. It is possible that these two earthquakes signal a reactivation of faulting at crustal depths beneath the Peru Monocline.

The intensity pattern from the 1999 earthquake shows many similarities to the intensity pattern of the 1972 earthquake. Some of this correspondence may be due to similar source mechanisms. Given these similar patterns, one can conclude that if a stronger earthquake were to occur in the same vicinity, Sterling-Rock Falls and Rockford would have a higher seismic risk than other metropolitan areas in northwestern Illinois, such as Peoria, Rock Island, and Dubuque. Chicago and its suburbs are relatively far from the epicenter of both the 1999 and 1972 earthquakes. Seismic risk in northeastern Illinois probably is controlled more by the occurrence of rare local earthquakes than by moderate earthquakes in northwestern Illinois.

A house built on a rock will stand better than one built on sand. This old proverb, originally applied to floods and winds, is equally valid for earthquake shaking. A close examination of both the 1972 and 1999 earthquakes reveals complex intensity patterns that appear to be controlled by local soil type and thickness. Even though Peoria, Rock Island, and Dubuque may not be at high risk because of seismic source considerations, each of these metropolitan areas has significant portions of their infrastructure within major river valleys. Buildings, bridges, and pipelines in these and other areas along the Illinois, Fox, Rock, and Mississippi River valleys are at increased risk from seismic ground shaking as a result of soil amplification effects.

As with all scientific investigations, the results from the study of this earthquake raise questions and suggest opportunities for further work. The small 1999 earthquake is probably typical for this area, and any new instrumentation installed in the area must be designed to extract the maximum amount of information possible from earthquakes of this magnitude when they occur. Research observatories in northern Illinois and southern Wisconsin need to be upgraded with more sensitive broadband recording devices. New observatories should be established in central Illinois and either western Illinois or eastern Iowa. A network of more numerous, but less sensitive (and less expensive) seismometers might also be deployed across northern Illinois. The objective of these new detectors would be to reduce the threshold for the accurate location of very small earthquakes to about m_b 2 and to determine source characteristics to about m_b 3.

The possible causative link between these two small earthquakes and the Peru Monocline deserves further study. In the past, regional seismicity appeared diffuse. Now, with two earthquakes in the same area (and possibly a third in 1881), attention can be focused on the Peru Monocline. Comparison with analogous structures in more earthquake-prone areas such as southern Illinois can provide some insight, but a deep, high-resolution seismic reflection transect across southern Lee County probably would yield more definitive results and needs to be undertaken.

The seismic hazards and risks in northern Illinois from local earthquakes need to be fully evaluated. According to the Frankel et al. (1996) hazard analysis, the threat from very large but distant earthquakes originating in the New Madrid Seismic Zone only dominate the earthquake hazard in northern Illinois for moderate to long period (1.0 second or greater) vibrations. For shorter period (higher frequency) vibrations, the hazards from local earthquakes (distances of about 50 km [30 mi]) in the M_w 5.0 to 6.0 range are greater than from large earthquakes in the New Madrid Seismic Zone (Harmsen et al. 1999). These results could be further refined as we continue to learn more about the seismicity of the central United States and northern Illinois (e.g., McNulty and Obermeier 1999, Newman et al. 1999).

Moderate earthquakes have been known to produce substantial damage in midcontinental areas that are not prepared for earthquakes (Bolt 1993).

In particular, soil amplification effects should be used in analyzing seismic risks for key structures such as bridges, pipelines, and large buildings in major river valleys. Seismic simulation techniques are well advanced (e.g., Graves 1993) and can be used to help understand the seismic risk in this area of relatively low seismicity. The intensity data from two local earthquakes can now provide a realistic calibration for earthquake simulations. As a result, mitigation efforts can be focused on more sensitive sites and can be justified from real, empirical data.

Acknowledgments

This report is the result of cooperation from hundreds of people. It has been particularly gratifying to witness the civic mindedness of not only the editors of the *Rockford Register Star, Freeport Journal Standard, Rochelle News Leader, Dixon Telegraph*, and *Fulton Press*, who graciously provided space in their publications, but also the hundreds of citizens who made the effort to complete the questionnaires and mail them to Champaign. Eileen Coleman, ISGS, painstakingly transcribed the responses into a workable database. James Dewey and Margaret Hopper, of the USGS National Earthquake Information Center, provided advice as well as their intensity data.

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Appendix 1

ISGS intensity survey after the September 2, 1999, earthquake. This form was distributed at an ISGS field trip on September 11, 1999, and edited versions were published in several local newspapers.

Northern Illinois Earthquake Survey
For Earthquake of September 2, 1999

Did you personally feel the earthquake? ☐ Yes ☐ No

Name (optional) ____________________

e-mail: (optional) ____________________

Your location when you felt the earthquake. Describe it as closely as you can by stating an address, cross streets, place names, in rural area, township, and section:

____

____

____

City: ____________________ Zip Code: __________

Your reaction was ☐ Little reaction ☐ Excitement ☐ Some fright

Did you have difficulty ☐ Standing up ☐ Walking

Vibration could be described as ☐ Weak ☐ Mild ☐ Moderate ☐ Strong

Complete this sentence: The vibrations felt like ____________________

____

Were you at ☐ Home ☐ Work ☐ School ☐ Inside ☐ Outside ☐ Other __________

If inside, what floor were you on? __________

What were you doing when the earthquake occurred?

☐ Lying down ☐ Sitting ☐ Standing ☐ Walking ☐ Other ____________________

____

Please describe any additional effects or damage observations from this earthquake: __________

____

____

____

Please return this form to:
Tim Larson
Illinois State Geological Survey
615 E. Peabody Drive
Champaign, IL 61820

Or e-mail to: tlarson@isgs.uiuc.edu

Appendix 2

Summary listing of ISGS intensity survey results gathered by town.[1]

				Latitude			Longitude		
Town	Zip	Count	MMI	Degree	Minute	Decimal degree	Degree	Minute	Decimal degree
Afton, WI	53501	1	2	42	38.52	42.6420	89	4.05	–89.0675
Albany	61230	1	3	41	47.53	41.7922	90	1.15	–90.0192
Amboy	61310	9	3	41	43.5	41.7250	89	20.2	–89.3367
Ashton	61006	1	3	41	52	41.8667	89	13.4	–89.2233
Baileyville	61007	1	3	42	11.8	42.1967	89	35.6	–89.5933
Beloit	53511	1	3	42	30.5	42.5083	89	1.9	–89.0317
Belvidere	61008	3	2	42	15.3	42.2550	88	50.4	–88.8400
Byron	61010	14	3	42	7.8	42.1300	89	15.3	–89.2550
Chadwick	61014	1	3	42	0.9	42.0150	89	53.3	–89.8883
Chana	61015	3	3	41	58.9	41.9817	89	13.3	–89.2217
Cherry Valley	61016	2	3	42	14.08	42.2347	88	56.93	–88.9488
Clinton, IA	52732	1	2	41	50.6	41.8433	90	11.6	–90.1933
Compton	61318	2	2	41	41.67	41.6945	89	4.87	–89.0812
Dakota	61018	1	3	42	23.3	42.3883	89	31.5	–89.5250
Davis	61019	2	3	42	25.8	42.4300	89	25.1	–89.4183
DeKalb	60115	1	2	41	55.8	41.9300	88	45.8	–88.7633
Dixon	61021	112	4	41	50.1	41.8350	89	29.2	–89.4867
Durand	61024	2	3	42	26.1	42.4350	89	20	–89.3333
Eldena	61324	2	3	41	46.2	41.7700	89	24.7	–89.4117
Elgin	60123	1	1	42	2.3	42.0383	88	17.4	–88.2900
Forreston	61030	1	4	42	7.7	42.1283	89	35	–89.5833
Franklin Grove	61021	9	4	41	50.5	41.8417	89	18	–89.3000
Freeport	61032	9	4	42	16.6	42.2767	89	36.1	–89.6017
Fulton	61252	7	3	41	52	41.8667	90	10.7	–90.1783
German Valley	61039	1	3	42	12.93	42.2155	89	28.4	–89.4733
Grand Detour	61021	6	4	41	53.9	41.8983	89	24.9	–89.4150
Harmon	61042	3	4	41	43.3	41.7217	89	33.3	–89.5550
Lanark	61046	2	3	42	6.1	42.1017	89	49.8	–89.8300
Leaf River	61047	3	2	42	7.53	42.1255	89	24.22	–89.4037
Lee Center	61331	2	2	41	44.9	41.7483	89	16.6	–89.2767
Lena	61048	1	3	42	22.9	42.3817	89	49.4	–89.8233
Lost Nation	61021	1	4	41	54.2	41.9033	89	21.36	–89.3560
Loves Park	61111	20	3	42	18.7	42.3117	89	3.4	–89.0567
Mchsney. Park	61115	4	2	42	22.5	42.3750	89	2.34	–89.0390
Mendota	61342	2	1	41	32.9	41.5483	89	7	–89.1167
Milledgeville	61051	4	4	41	57.8	41.9633	89	46.4	–89.7733
Morrison	61270	2	2	41	48.5	41.8083	89	58	–89.9667
Mt. Carroll	61053	4	3	42	5.8	42.0967	89	58.5	–89.9750
Mt. Morris	61054	6	3	42	3	42.0500	89	26	–89.4333
Nelson	61021	1	4	41	47.78	41.7963	89	36.1	–89.6017
Normal	61761	1	1	40	30.5	40.5083	88	59.2	–88.9867
Ohio	61344	2	3	41	33.5	41.5583	89	27.6	–89.4600
Oregon	61061	17	4	42	0.7	42.0117	89	20.1	–89.3350
Ottawa	61350	2	1	41	21.6	41.3600	88	50.8	–88.8467
Palmyra	61021	4	4	39	26	39.4333	89	59.6	–89.9933
Pecatonica	61063	4	3	42	18.7	42.3117	89	21.6	–89.3600
Penrose	61081	1	4	41	53.25	41.8875	89	40.07	–89.6678
Polo	61064	5	4	41	59.1	41.9850	89	34.8	–89.5800
Rochelle	61068	10	4	41	55.5	41.9250	89	4.2	–89.0700
Rock City	61070	1	3	42	24.8	42.4133	89	28.08	–89.4680
Rock Falls	61071	3	4	41	46.6	41.7767	89	41.1	–89.6850
Rockford	61101	12	4	42	17.7	42.2950	89	6.6	–89.1100
Rockford	61102	9	4	42	15.5	42.2583	89	7.5	–89.1250
Rockford	61103	32	4	42	18.75	42.3125	89	5.25	–89.0875

				Latitude			Longitude		
Town	Zip	Count	MMI	Degree	Minute	Decimal degree	Degree	Minute	Decimal degree
Rockford	61104	19	4	42	15.56	42.2593	89	5.06	–89.0843
Rockford	61105	1	3	42	19.36	42.3227	89	8.18	–89.1363
Rockford	61107	54	4	42	16.94	42.2823	89	1.68	–89.0280
Rockford	61108	24	4	42	15.28	42.2547	89	0.93	–89.0155
Rockford	61109	19	4	42	12.68	42.2113	89	3.56	–89.0593
Rockford	61110	1	3	42	16.53	42.2755	89	5.06	–89.0843
Rockford	61114	15	4	42	18.33	42.3055	89	1.13	–89.0188
Rockton	61072	5	3	42	27.3	42.4550	89	4.4	–89.0733
Roscoe	61073	4	3	42	25.1	42.4183	89	0.7	–89.0117
Savanna	61074	2	2	42	5.3	42.0883	90	8.4	–90.1400
Scales Mound	61075	1	2	42	28.6	42.4767	90	15.1	–90.2517
Seward	61077	1	3	42	14.2	42.2367	89	21.5	–89.3583
Shirland	61072	1	3	42	26.67	42.4445	89	11.85	–89.1975
Springfield	62703	1	1	39	48	39.8000	89	38.9	–89.6483
Sterling	61081	10	4	41	47.6	41.7933	89	41.7	–89.6950
Stillman Valley	61084	2	3	42	6.43	42.1072	89	10.75	–89.1792
Winnebago	61088	3	3	42	15.97	42.2662	89	14.47	–89.2412
Woodstock	60098	1	2	42	19.1	42.3183	88	26.8	–88.4467
Woosung	61091	1	2	41	54.2	41.9033	89	32.5	–89.5417
Geneseo	phone	-	1	41	27.2	41.4533	90	9.4	–90.1567
Hooppole	phone	-	2	41	31.4	41.5233	89	54.7	–89.9117
Janesville, WI	phone	-	1	42	40.9	42.6817	89	1.2	–89.0200
Lyndon	phone	-	2	41	42.9	41.7150	89	55.5	–89.9250
Moline	phone	-	1	41	30	41.5000	90	30.5	–90.5083
Monroe, WI	phone	-	1	42	36	42.6000	89	38.3	–89.6383
Princeton	phone	-	1	40	55.7	40.9283	89	45.5	–89.7583
Prophetstown	phone	-	2	41	30.3	41.5050	89	56.2	–89.9367

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[1] Count is number of responses from that town. MMI is Modified Mercalli Intensity assigned to that location based on consensus of responses. Location data are taken from atlases of Illinois and are generally accurate to 0.1E, sometimes 0.01E. Rural addresses are not differentiated from postal center unless respondent provided separate location information (e.g., Grand Detour and Nachusa have Dixon postal codes). Multiple zip codes for Rockford have been differentiated and located based on the approximate centroid of that postal zone. Some data were gathered by phone interview of newspaper reporters and are included at the end of this list and differentiated by the term *phone* in the zip code column.

Appendix 3

USGS intensity data[1] for the northern Illinois earthquake September 2, 1999.

Intensity	State	Town	Latitude	Longitude	Source
0	IA	Bettendorf	41.5240	–90.5160	Card
0	IA	Camanche	41.7880	–90.2560	Card
4	IA	Clinton	41.8444	–90.1886	Web[2]
0	IA	Clinton	41.8440	–90.1890	Card
0	IA	Davenport	41.5667	–90.5381	Card
0	IA	De Witt	41.8230	–90.5380	Card
0	IA	Dubuque	42.5010	–90.6640	Card
0	IA	Eldridge	41.6580	–90.5840	Card
0	IA	Le Claire	41.6000	–90.3480	Card
0	IA	Maquoketa	42.0690	–90.6660	Card
0	IA	Pleasant Valley	41.5700	–90.4230	Card
0	IA	Preston	42.0500	–90.4140	Card
0	IA	Princeton	41.6750	–90.3400	Card
0	IA	Wilton	41.5890	–91.0170	Card
0	IL	Addison	41.9330	–87.9830	Card
2	IL	Albany	41.7830	–90.2170	Card
0	IL	Aledo	41.2000	–90.7330	Card
0	IL	Algonquin	42.1670	–88.2670	Card
5	IL	Amboy	41.7167	–89.3500	Web
0	IL	Amboy	41.7170	–89.3500	Card
0	IL	Annawan	41.4000	–89.9170	Card
0	IL	Antioch	42.4670	–88.1000	Card
3	IL	Ashton	41.0330	–89.2330	Card
3	IL	Ashton	41.0330	–89.2330	Card
0	IL	Barrington	42.1500	–88.1170	Card
0	IL	Batavia	41.8500	–88.3000	Card
0	IL	Bellwood	41.4670	–87.8170	Card
0	IL	Belvidere	42.2500	–88.8330	Card
0	IL	Berwyn	41.8500	–87.7900	Card
0	IL	Big Rock	41.7670	–88.5500	Card
0	IL	Bloomingdale	41.9500	–88.0830	Card
0	IL	Bloomington	40.4830	–88.9830	Card
0	IL	Blue Island	41.6670	–87.6830	Card
0	IL	Bourbonnais	41.1500	–87.8830	Card
0	IL	Bradford	41.1830	–89.6500	Card
0	IL	Bradley	41.1670	–87.8670	Card
0	IL	Brookfield	41.8170	–87.8500	Card
0	IL	Buda	41.3330	–89.6830	Card
0	IL	Bureau	41.2830	–89.3670	Card
0	IL	Burlington	42.0500	–88.5500	Card
3	IL	Byron	42.1500	–89.2830	Card
4	IL	Byron	42.1500	–89.2833	Web
4	IL	Byron	42.1500	–89.2833	Web
5	IL	Byron	42.1500	–89.2833	Web
4	IL	Byron	42.1500	–89.2833	Web
0	IL	Canton	40.5500	–90.0330	Card
0	IL	Carpentersville	42.2000	–88.3170	Card
0	IL	Cary	42.2170	–88.2330	Card
0	IL	Chadwick	42.0170	–89.8830	Card
0	IL	Cherry	41.4330	–89.2170	Card
0	IL	Cherry Valley	42.2170	–88.9830	Card
0	IL	Chillicothe	40.9170	–89.5170	Card
1	IL	Clinton	40.1527	–88.9593	Web news
0	IL	Colona	41.4830	–90.3500	Card
1	IL	Compton	41.7000	–89.0830	Card
0	IL	Creston	41.9330	–88.9670	Card
0	IL	Crystal Lake	42.2500	–88.3170	Card
0	IL	Dalzell	41.3670	–89.1670	Card
0	IL	Des Plaines	42.0830	–87.9170	Card

Intensity	State	Town	Latitude	Longitude	Source
4	IL	Dixon	41.8500	–89.4830	Card
3	IL	Dixon	41.8500	–89.4833	Web
3	IL	Dixon	41.8500	–89.4833	Web
3	IL	Dixon	41.8500	–89.4833	Web news
0	IL	Dolton	41.6500	–87.6170	Card
0	IL	Dubuque	42.5010	–90.6640	Card
0	IL	Dundee	42.1000	–88.2830	Card
0	IL	Durand	42.4330	–89.3330	Card
0	IL	Dwight	41.0830	–88.4330	Card
0	IL	Earlville	41.5830	–88.9170	Card
0	IL	East Dubuque	42.5000	–90.6170	Card
0	IL	Elburn	41.9000	–88.4670	Card
0	IL	Elgin	42.0330	–88.3000	Card
0	IL	Elizabeth	42.3170	–90.2170	Card
0	IL	Elmhurst	41.9830	–87.9830	Card
0	IL	Erie	41.6500	–90.0830	Card
0	IL	Eureka	40.7330	–89.2670	Card
0	IL	Evanston	42.0330	–87.7000	Card
0	IL	Forest Park	41.8500	–87.7830	Card
5	IL	Frankfort	41.5000	–87.8500	Card
3	IL	Franklin Grove	41.8330	–89.3000	Card
0	IL	Franklin Park	41.9330	–87.8670	Card
0	IL	Freeport	42.3000	–89.6170	Card
4	IL	Fulton	41.8670	–90.1330	Card
4	IL	Fulton	41.8667	–90.1333	Web
1	IL	Fulton	41.8667	–90.1333	Web news
3	IL	Galena	42.4167	–90.2667	Web
0	IL	Galena	42.4170	–90.2670	Card
0	IL	Galesburg	40.9330	–90.3670	Card
0	IL	Galva	41.1670	–90.0330	Card
0	IL	Geneseo	41.4330	–90.1500	Card
0	IL	Geneva	41.8830	–88.3170	Card
0	IL	Genoa	42.1000	–88.6830	Card
0	IL	Glen Ellyn	41.8830	–88.0670	Card
0	IL	Glencoe	42.1670	–87.7670	Card
0	IL	Glenwood	41.5500	–87.6170	Card
0	IL	Grayslake	42.3500	–88.0400	Card
0	IL	Gurnee	42.3830	–87.9000	Card
0	IL	Hanover Park	42.0000	–88.1400	Card
5	IL	Harmon	41.7170	–89.5500	Card
0	IL	Harvard	42.4170	–88.6330	Card
0	IL	Hebron	42.4670	–88.4330	Card
0	IL	Hennepin	41.2500	–89.3500	Card
0	IL	Henry	41.1170	–89.3830	Card
0	IL	Highland Park	42.1830	–87.7830	Card
0	IL	Highwood	42.2170	–87.8330	Card
0	IL	Hinckley	41.7670	–88.6330	Card
0	IL	Hines	41.8670	–87.8500	Card
0	IL	Hooppole	41.5170	–89.9170	Card
0	IL	Huntley	42.1830	–88.4330	Card
0	IL	Joliet	41.5330	–88.0830	Card
0	IL	Kankakee	41.1000	–87.8670	Card
0	IL	Kirkland	42.1000	–88.8500	Card
0	IL	La Salle	41.3000	–89.0830	Card
0	IL	Ladd	41.3830	–89.2330	Card
0	IL	Lake Bluff	42.2670	–87.8330	Card
0	IL	Lake Zurich	42.1830	–88.1000	Card
2	IL	Lanark	42.1000	–89.8500	Card
0	IL	Lee	41.8000	–88.9330	Card
0	IL	Leland	41.6170	–88.8000	Card
0	IL	Lena	42.3830	–89.8330	Card

continued

Appendix 3 *continued*

USGS intensity data[1] for the northern Illinois earthquake September 2, 1999.

Intensity	State	Town	Latitude	Longitude	Source
0	IL	Libertyville	2.3000	–87.9830	Card
0	IL	Lincolnshire	42.1884	–87.9299	Card
0	IL	Lindenwood	42.0500	–89.0330	Card
0	IL	Lisle	41.8000	–88.0830	Card
0	IL	Lombard	41.8830	–88.0170	Card
4	IL	Lyndon	41.7170	–89.9330	Card
0	IL	Lyons	41.7830	–87.7500	Card
0	IL	Malden	41.4170	–89.3670	Card
0	IL	Malta	41.9330	–88.8670	Card
0	IL	Manlius	41.4500	–89.6670	Card
0	IL	Marseilles	41.3330	–88.7000	Card
0	IL	Maywood	41.8750	–87.8600	Card
0	IL	Mc Henry	42.3500	–88.2670	Card
0	IL	Melrose Park	41.8830	–87.8500	Card
0	IL	Mendota	41.5670	–89.1000	Card
0	IL	Midlothian	41.6170	–87.7170	Card
0	IL	Milan	41.4500	–90.5670	Card
4	IL	Milledgeville	41.9670	–89.9330	Card
0	IL	Minonk	40.9170	–89.0000	Card
2	IL	Moline	41.5000	–90.5667	Web
0	IL	Moline	41.5000	–90.5670	Card
0	IL	Monmouth	40.9000	–90.6330	Card
0	IL	Montgomery	41.7330	–88.4330	Card
0	IL	Morris	41.3670	–88.4170	Card
3	IL	Morrison	41.8000	–89.9500	Web news
2	IL	Morrison	41.8000	–89.9500	Card
4	IL	Morrison	41.8000	–89.9500	Web
0	IL	Morton	40.6170	–89.4670	Card
0	IL	Morton Grove	42.0500	–87.7830	Card
3	IL	Mount Carroll	42.0830	–89.9830	Card
0	IL	Mount Morris	42.0500	–89.4330	Card
0	IL	Mount Prospect	42.0670	–87.9330	Card
4	IL	Mt. Morris	42.0500	–89.4333	Web
3	IL	Mt. Morris	42.0500	–89.4333	Web
5	IL	Nachusa	41.8330	–89.3830	Card
0	IL	Naperville	41.7830	–88.1500	Card
0	IL	Neponset	41.3000	–89.7830	Card
0	IL	New Bedford	41.5170	–89.7170	Card
0	IL	New Lenox	41.5170	–87.9670	Card
0	IL	Newark	41.5330	–88.5830	Card
0	IL	Normal	40.5170	–88.9830	Card
0	IL	North Aurora	41.8170	–88.3330	Card
0	IL	North Chicago	42.3170	–87.8500	Card
0	IL	Oak Brook	41.8369	–87.9527	Card
0	IL	Oak Park	41.8830	–87.7170	Card
0	IL	Oglesby	41.2670	–89.0330	Card
4	IL	Ohio	41.5670	–89.4670	Card
0	IL	Olympia Fields	41.5330	–87.6830	Card
5	IL	Oregon	42.0333	–89.3333	Web
0	IL	Oregon	42.0330	–89.3330	Card
3	IL	Oregon	42.0330	–89.3330	Card
4	IL	Oregon	42.0333	–89.3333	Web
5	IL	Oregon	42.0333	–89.3333	Web
5	IL	Oregon	42.0333	–89.3333	Web
4	IL	Oregon	42.0333	–89.3333	Web
4	IL	Oregon	42.0333	–89.3333	Web
4	IL	Oregon	42.0333	–89.3333	Web
0	IL	Orland Park	41.6330	–87.8670	Card

Intensity	State	Town	Latitude	Longitude	Source
0	IL	Oswego	41.6830	–88.3500	Card
0	IL	Ottawa	41.3500	–88.8330	Card
0	IL	Palatine	42.1170	–88.0500	Card
0	IL	Palos Park	41.6670	–87.8330	Card
2	IL	Pekin	40.5667	–89.6333	Web
0	IL	Peru	41.3170	–89.1500	Card
0	IL	Plano	41.6670	–88.5330	Card
3	IL	Polo	41.9830	–89.5830	Card
0	IL	Pontiac	40.8830	–88.6000	Card
0	IL	Port Byron	41.5830	–90.3330	Card
0	IL	Posen	41.6330	–87.6830	Card
0	IL	Prophetstown	41.6700	–90.9400	Card
0	IL	Richmond	42.4670	–88.3000	Card
0	IL	River Grove	41.9170	–87.8170	Card
3	IL	Rochelle	41.9167	–89.0500	Web
4	IL	Rock Falls	41.7670	–89.7000	Card
4	IL	Rockford	42.3010	–89.1040	Web
2	IL	Rockford	42.3000	–89.0830	Card
5	IL	Rockford	42.3000	–89.0833	Web
3	IL	Rockford	42.3000	–89.0833	Web
2	IL	Rockford	42.3000	–89.0833	Web
3	IL	Rockford	42.2815	–89.0269	Web
3	IL	Rockford	42.2815	–89.0269	Web
3	IL	Rockford	42.2553	–89.0812	Web
4	IL	Rockford	42.2553	–89.0812	Web
3	IL	Rockford	42.3000	–89.0833	Web
0	IL	Rome	40.8830	–89.5170	Card
0	IL	Roselle	41.9830	–88.0830	Card
0	IL	Round Lake	42.3830	–88.1330	Card
0	IL	Saint Charles	41.9170	–88.3170	Card
0	IL	Seatonville	41.3670	–89.4000	Card
0	IL	Seneca	41.3330	–88.6000	Card
0	IL	Shabbona	41.7670	–88.8670	Card
0	IL	Shannon	42.1500	–89.7330	Card
0	IL	Sheffield	41.3670	–89.7170	Card
0	IL	Sheridan	41.5330	–88.6830	Card
0	IL	Silvis	41.5000	–90.4000	Card
0	IL	Skokie	42.0330	–87.7500	Card
0	IL	Somonauk	41.6330	–88.6830	Card
0	IL	South Elgin	42.0000	–88.3000	Card
4	IL	Sterling	41.7833	–89.7000	Web
3	IL	Sterling	41.7830	–89.7000	Card
4	IL	Sterling	41.7833	–89.7000	Web
4	IL	Sterling	41.7833	–89.7000	Web
4	IL	Sterling	41.7833	–89.7000	Web
4	IL	Sterling	41.7833	–89.7000	Web
5	IL	Sterling	41.7833	–89.7000	Web
0	IL	Steward	41.8500	–89.0170	Card
3	IL	Stillman Valley	42.1170	–89.1830	Card
3	IL	Stillman Valley	42.1167	–89.1833	Web
0	IL	Stockton	42.3500	–90.0330	Card
2	IL	Sublette	41.6500	–89.2330	Card
0	IL	Sugar Grove	41.7670	–88.4500	Card
0	IL	Summit Argo	41.7834	–87.8099	Card
0	IL	Sycamore	42.0000	–88.6670	Card
0	IL	Tampico	41.6330	–89.7830	Card
0	IL	Techny	42.1170	–87.8170	Card
0	IL	Tiskilwa	41.3000	–89.5000	Card
0	IL	Tonica	41.2170	–89.0670	Card
0	IL	Triumph	41.5000	–89.0170	Card
0	IL	Troy Grove	41.4670	–89.0830	Card

continued

Appendix 3 *continued*

USGS intensity data[1] for the northern Illinois earthquake September 2, 1999.

Intensity	State	Town	Latitude	Longitude	Source
0	IL	Union	42.2330	–88.5500	Card
0	IL	Van Orin	41.5500	–89.3500	Card
0	IL	Vernon Hills	42.2327	–87.9720	Card
0	IL	Villa Park	41.8830	–87.9830	Card
4	IL	Walnut	41.5500	–89.6000	Card
0	IL	Warren	42.4830	–89.9830	Card
0	IL	Washburn	40.9170	–89.2830	Card
0	IL	Waterman	41.7670	–88.7670	Card
0	IL	Wauconda	42.2670	–88.1330	Card
0	IL	Wenona	41.0670	–89.0500	Card
0	IL	West Brooklyn	41.7000	–89.1500	Card
0	IL	Westmont	41.8000	–87.9500	Card
0	IL	Wheaton	41.8670	–88.1170	Card
5	IL	Whiteside County	41.7508	–89.9113	Web news
0	IL	Willow Springs	41.8000	–88.8670	Card
0	IL	Wilmette	42.0670	–87.7170	Card
0	IL	Wilmington	41.3000	–88.1500	Card
0	IL	Winfield	41.1670	–88.8670	Card
0	IL	Winnebago	42.2500	–89.2000	Card
0	IL	Winnetka	42.0830	–87.7170	Card
0	IL	Winslow	42.5000	–89.8000	Card
0	IL	Wood Dale	41.9500	–87.9330	Card
0	IL	Woodhull	41.1830	–90.3330	Card
0	IL	Woodstock	42.3330	–88.4670	Card
0	IL	Wyanet	41.3670	–89.5830	Card
0	IL	Wyoming	41.0670	–89.7670	Card
0	IL	Yorkville	41.6330	–88.4500	Card
0	WI	Brodhead	42.6170	–89.3830	Card
0	WI	Darlington	42.7500	–90.5000	Card
0	WI	Delavan	42.6500	–88.5830	Card
0	WI	East Troy	42.7830	–88.4000	Card
0	WI	Edgerton	42.8500	–89.0830	Card
0	WI	Elkhorn	42.6670	–88.5000	Card
5	WI	Janesville	42.6833	–89.0000	Web
0	WI	Janesville	42.6830	–89.0000	Card
3	WI	Janesville	42.6833	–89.0000	Web
0	WI	Jefferson	43.0000	–88.8000	Card
0	WI	Juda	42.5830	–89.5000	Card
0	WI	Lake Geneva	42.6170	–88.4170	Card
2	WI	Milwaukee	43.1626	–87.9890	Web
0	WI	Monroe	42.5830	–89.6500	Card
0	WI	Mukwonago	42.3670	–88.3330	Card
0	WI	Platteville	42.7500	–90.4830	Card
3	WI	Spring Green	43.1833	–90.0667	Web
0	WI	Stoughton	42.9170	–89.2330	Card
0	WI	Whitewater	42.8330	–88.7330	Card
0	WI	Wilmot	42.5170	–88.1830	Card

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[1] National Earthquake Information Center, Margaret G. Hopper (hopper@ghtmail.cr.usgs.gov/).

[2] Web questionnaire.