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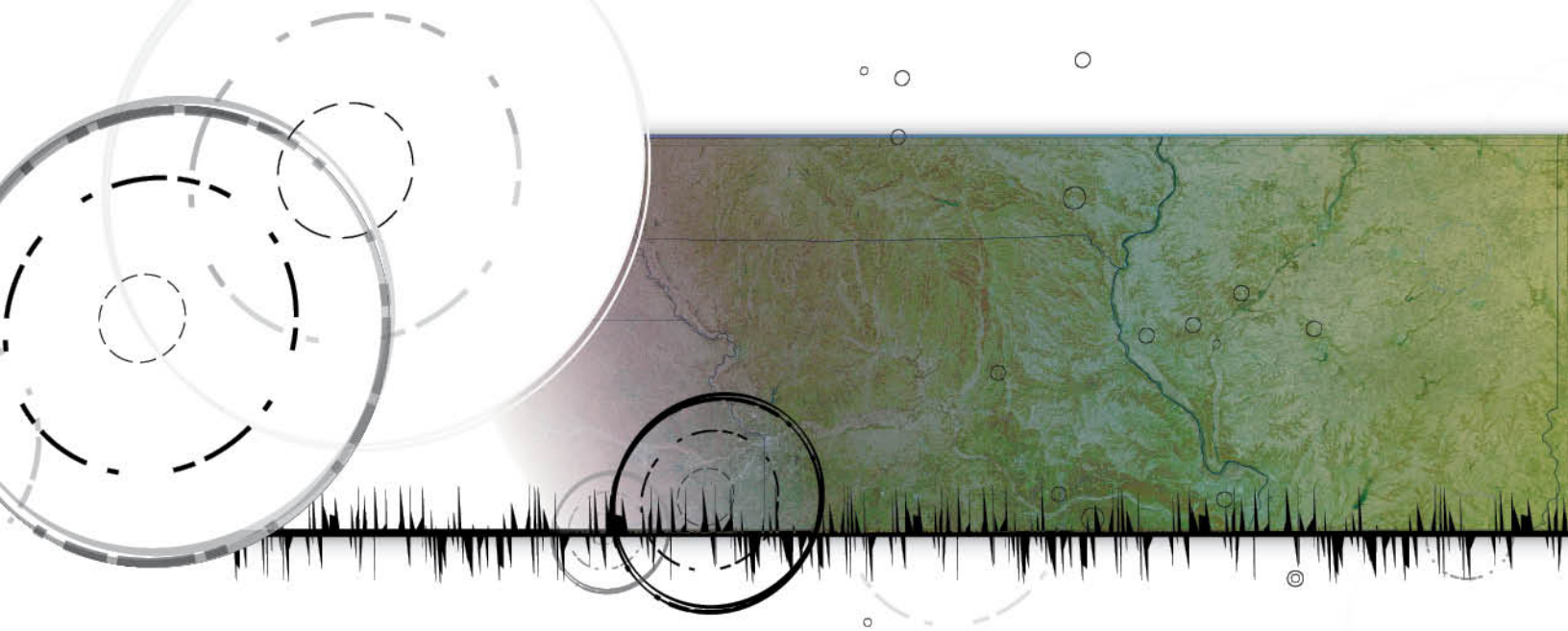
Putting Down Roots in Earthquake Country

Your Handbook for the Central United States

General Information Product 119

U.S. Department of the Interior
U.S. Geological Survey



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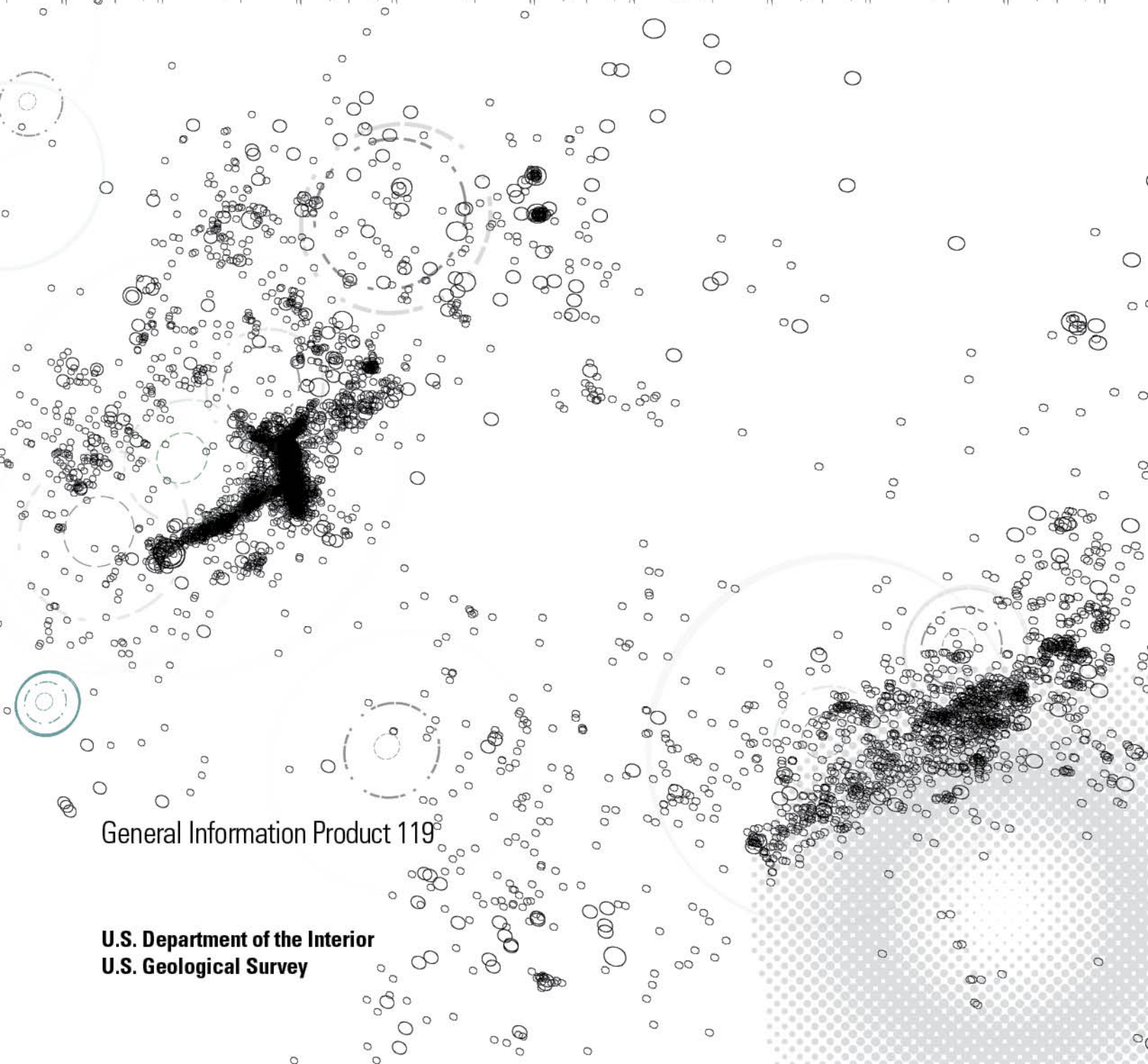
Putting Down Roots in Earthquake Country—
Your Handbook for Earthquakes in the Central United States



General Information Product 119

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U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
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Prepared by the U.S. Geological Survey, in cooperation with the Central U.S. Earthquake Consortium (CUSEC), the Association of CUSEC State Geologists (Alabama, Arkansas, Indiana, Illinois, Kentucky, Mississippi, Missouri, and Tennessee), the University of Memphis Center for Earthquake Research and Information (CERI), and the Southern California Earthquake Center (SCEC).
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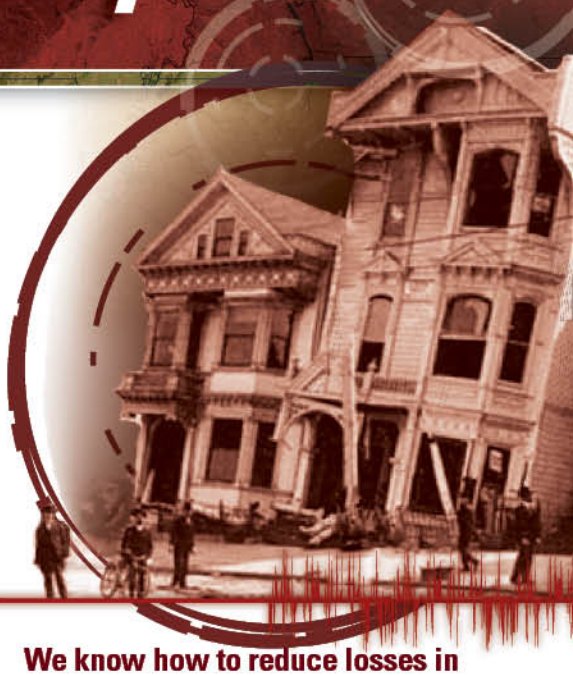
Contents

Photo of homes courtesy of Bardia Khajenoori.

The Central United States Is "Earthquake Country"



This handbook provides information about the threat posed by earthquakes in the Central United States, particularly along the New Madrid seismic zone, and explains how you can prepare for, survive, and recover from these inevitable events. If you live or work in the Central United States, you need to know why you should be concerned about earthquakes, what you can expect during and after an earthquake, and what you need to do beforehand to be safe and protect your property.

Much has been learned about the earthquake threat and vulnerability in the Central United States—

We know earthquakes occur here.

The Central United States is not on a plate boundary where most of the world's earthquakes occur, but moderate to light earthquakes are not infrequent in the region. More importantly, large, damaging earthquakes have occurred here in the past and are expected to occur again in the future.

We know where earthquakes are likely to occur and what they can do.

Large, damaging earthquakes in the Central United States are most likely to occur in the New Madrid and Wabash Valley seismic zones. These areas encompass eight States and several large cities in the Nation's heartland and are characterized by several hundred smaller earthquakes every year. Moderate to large earthquakes (generally **magnitude** 6 and greater), although rare, can kill and injure many people and cause substantial damage to buildings, roads, bridges, and utilities.

We know how to reduce losses in future large earthquakes.

Most casualties and economic losses result from damage to poorly maintained older buildings and their unrestrained contents. Improved building codes can be enforced, older buildings can be strengthened, and steps can be taken to upgrade schools and other critical facilities. Although some Central U.S. residents have taken steps to prepare for earthquakes—such as securing their homes to better withstand shaking, creating emergency plans and disaster supply kits, and holding home earthquake drills—most have not.

Technical terms used throughout this pamphlet (shown in boldface) are explained in the Glossary (page 44).

We have not done enough to be prepared for the next large earthquake—

Few households have disaster plans.

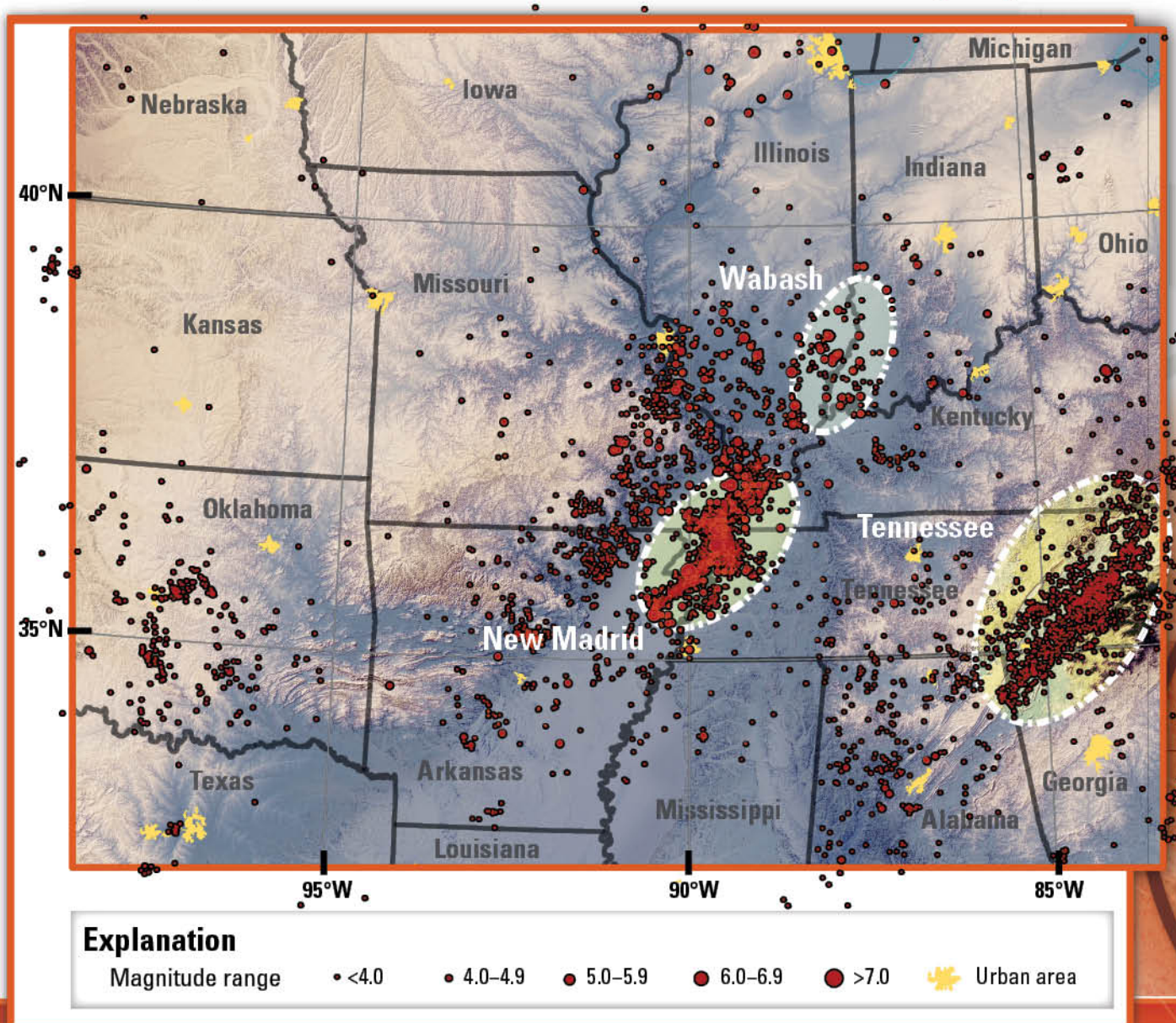
If an earthquake occurred right now, where would you go to be safe? If you are at work and your children are at school when the earthquake occurs, how and where will you meet?

Few households have disaster supply kits.

You will likely be on your own without vital services in the hours and days following an earthquake. Are you prepared with water, food, first aid supplies, and medications?

Few home owners have taken steps to retrofit their older homes.

The Central United States has many houses that predate modern earthquake building codes. Is your home bolted to its foundation? If you live in an older building, has it been **retrofitted**? Is your water heater strapped? Could unsecured furniture or objects fall and cause injury or damage? Do you have an old chimney that needs strengthening?



Earthquakes recorded in the Central United States since 1973. The sizes of the red dots are proportional to the magnitudes of the earthquakes—the large majority of recorded events are below magnitude 4. The locations of the New Madrid, Wabash Valley, and eastern Tennesse seismic zones (white outline) are also shown.

The Central United States Is Seismically Active

Earthquakes typically occur along plate boundaries. Much like cracks in the broken shell of a hard-boiled egg, plate boundaries mark where the Earth's **tectonic plates** rub as they move past each other, generating earthquakes as they go. But earthquakes occur away from plate boundaries as well—in intraplate regions in the center of continents.

In the Central United States—the region extending over 1,000 miles from the Rocky Mountains to the Appalachian Mountains—approximately 150 earthquakes are recorded every year above magnitude (M) 1.0. These intraplate earthquakes are most prominent in the New Madrid and Wabash Valley seismic zones, but they also occur outside these seismic belts, in places like Nebraska, Ohio, Oklahoma, and Mississippi (see figure, facing page).

Although most Central U.S. earthquakes are too small to be felt, a handful have caused measurable or significant damage. Damaging earthquakes in the Central United States of magnitude 5.0 and larger have occurred within well populated areas (see table, right).

The current seismic activity and the history of earthquakes in the region tell us that the Central United States has the potential to produce very large earthquakes near heavily populated areas. But how significant is the threat? How likely are large earthquakes to occur, and what is the chance that the shaking they cause will be damaging?

This section (pages 3–17) describes where earthquakes occur in the Central United States and explains how earthquakes will shake the ground and cause damage by shaking, **liquefaction**, and **landslides**.

Rescue dog photograph courtesy of PartnerHund.com

Historical earthquakes of approximate magnitude 5.0 and larger in the Central United States. Magnitudes for events prior to the mid-1900s are approximate and are based on historical accounts and other indirect estimates.

Year	Magnitude	Location
1812	7.7	New Madrid Region, MO
1811	7.7	New Madrid Region, AR
1812	7.5	New Madrid Region, MO
1811	7.0	New Madrid Region, AR
1895	6.6	Charleston, MO
1843	6.0	New Madrid Region, AR
1952	5.5	Oklahoma City, OK
1968	5.5	Wabash River Valley, IL
1937	5.4	Western Ohio
2008	5.4	Mt. Carmel, IL
1978	5.3	Abilene, TX
1838	5.2	Wabash River Valley, IL
1891	5.2	Southern Illinois
1980	5.2	Maysville, KY
1867	5.1	Manhattan, KS
1877	5.1	Lincoln, NE
1903	5.1	New Madrid Region, MO
1909	5.1	Chicago, IL
1909	5.1	Wabash River Valley, IL
1917	5.1	Wabash River Valley, IL
1987	5.1	Olney, IL
1865	5.0	Memphis, TN
1937	5.0	Western Ohio
1976	5.0	New Madrid Region, AR
1986	5.0	Northeastern Ohio
1990	5.0	New Madrid Region, MO
1991	5.0	New Madrid Region, MO

New Madrid Seismic Zone

In the winter of 1811–1812, the central Mississippi Valley was struck by three of the most powerful earthquakes in U.S. history. Survivors reported that the earthquakes caused cracks to open in the Earth's surface, the ground to roll in visible waves, and large areas of land to sink or rise. The crew of the *New Orleans* (the first steamboat on the Mississippi River, on her maiden voyage at the time) reported mooring to an island only to awake in the morning and find that the island had disappeared below the waters of the Mississippi River (Latrobe, 1871). By winter's end, after thousands of aftershocks, few houses within 250 miles of the Mississippi River town of New Madrid, Mo., remained unscathed. Damage from the quakes was reported as far away as Charleston, S.C., and Washington, D.C.

New Madrid Earthquakes—How Big Were They?

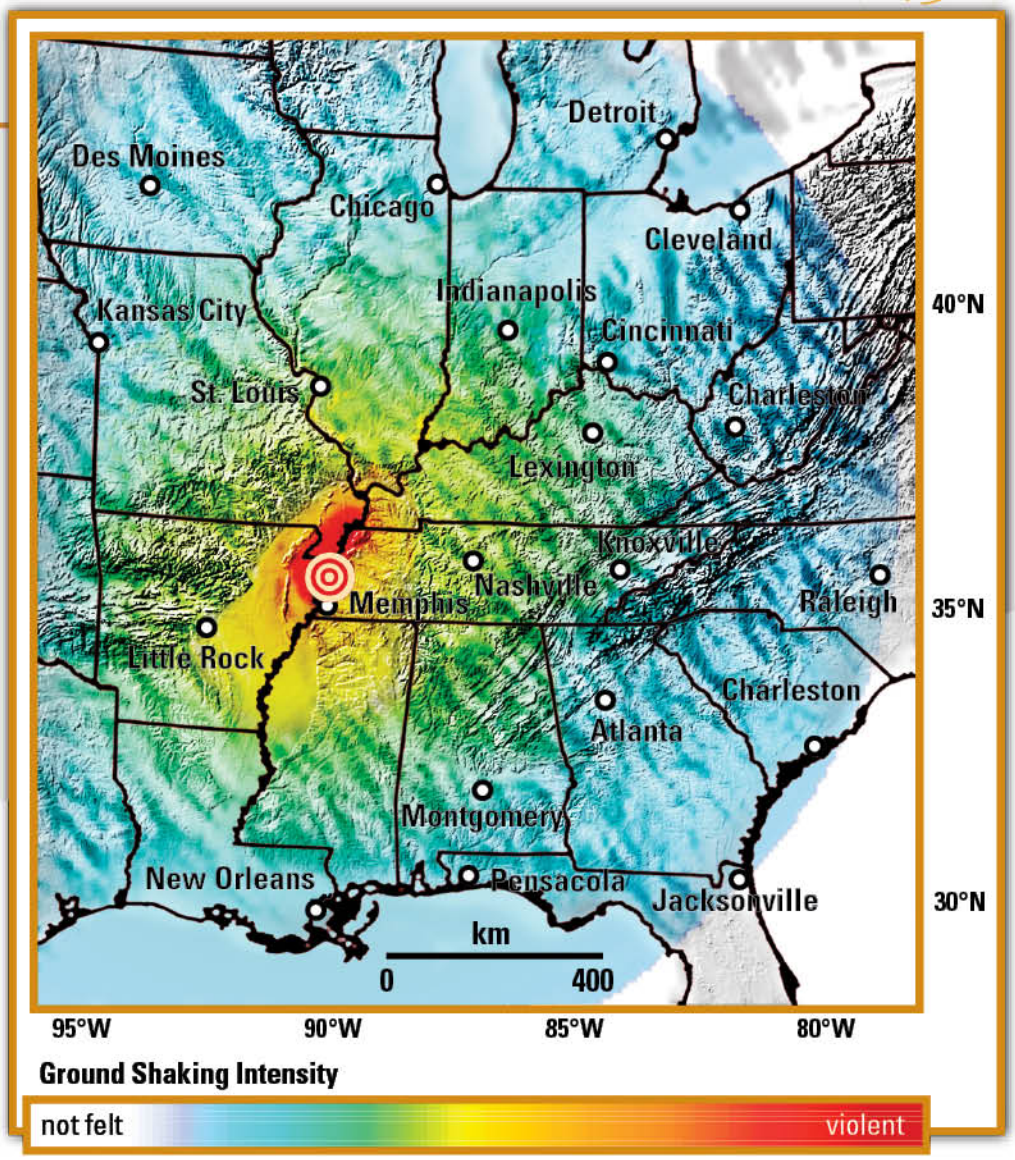
Because the New Madrid earthquakes of 1811–1812 predated the development of the **seismograph**, and because the region was only sparsely populated and thus historical accounts are limited, it is a matter of debate just how big these **temblors** were—estimates range between magnitude 7 and 8 (see figure, facing page). Uncertainty is large, but even a magnitude 7 quake can be quite devastating, as evidenced by the January 2010 earthquake in Haiti that took the lives of over 200,000 people. The New Madrid region is no longer sparsely populated; over 3 million people live in the region today. Consequently, the next earthquake will affect a much larger population, making it exceedingly difficult to quickly restore essential services such as water, gas, electricity, and communications. That is why it is essential for people to be prepared.

New Madrid Earthquake historical marker. (Photo courtesy of Jimmy S. Emerson, DVM.)

ABOVE Artist's concept of public reaction to the powerful New Madrid earthquakes of 1811–1812. (19th Century illustration used by permission of State Historical Society of Missouri, Columbia, Mo.)

Is a Failed Rift a Source of the Seismicity?

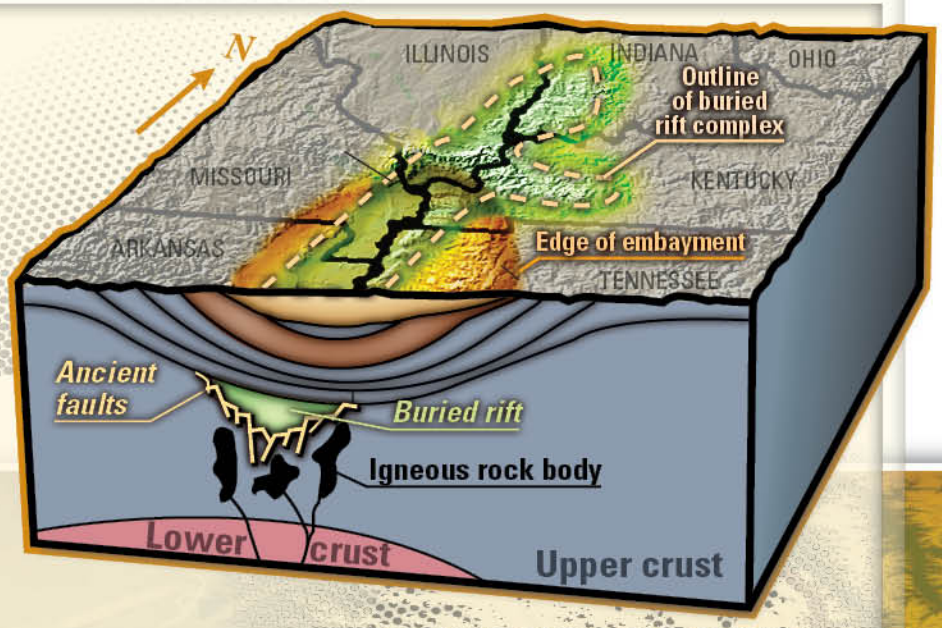
The New Madrid seismic zone is made up of reactivated **faults** that formed when what is now North America began to split or rift apart approximately 500 million years ago. The resulting rift system died out before an ocean basin was formed, but a deep zone of weakness was created. The resulting Reelfoot rift (see inset, below) has since been deeply buried by up to 5 miles of younger sediments and cannot be seen at the surface. Seismicity may be concentrated in the New Madrid area because the rocks here are mechanically weaker than surrounding regions.

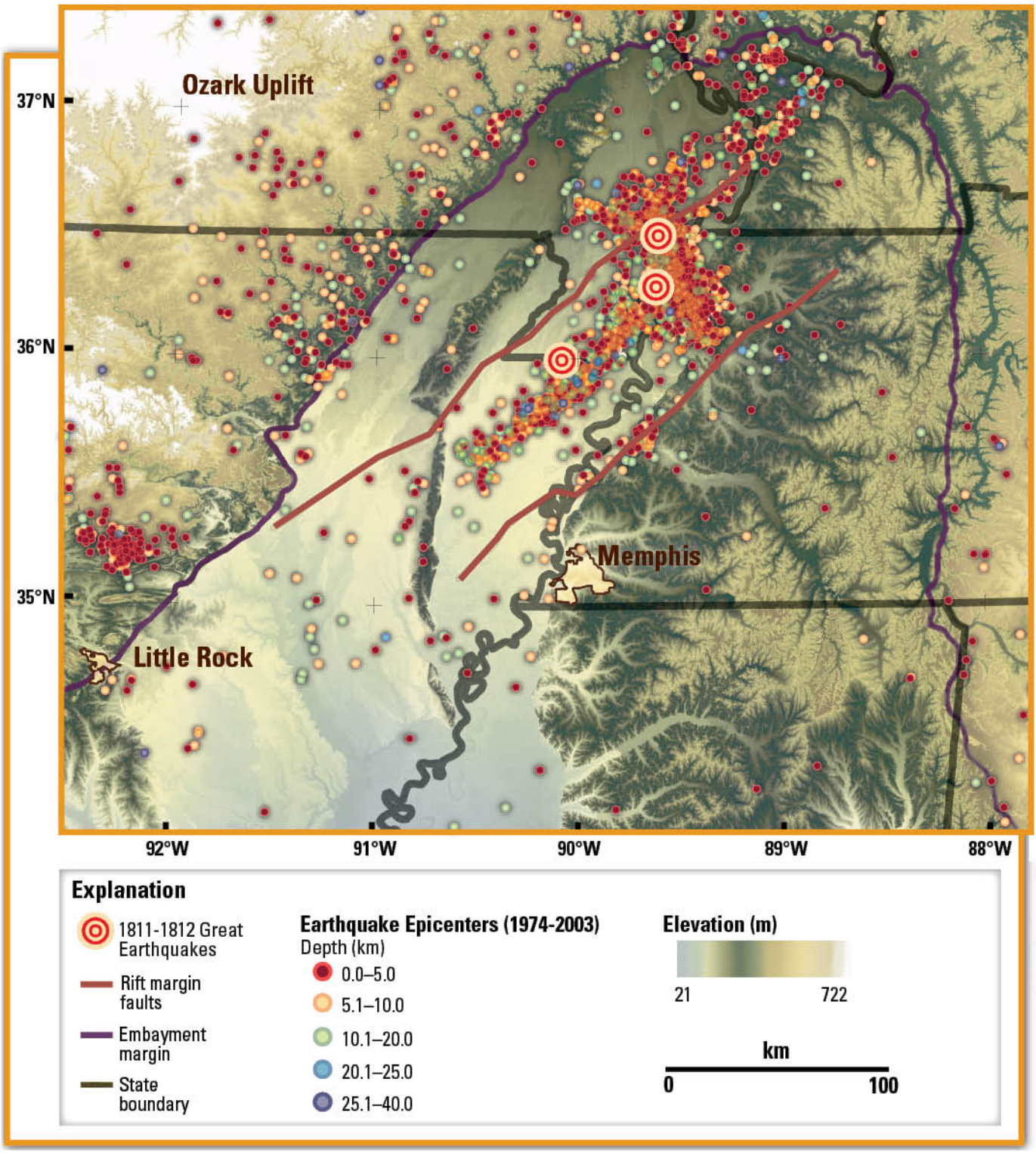


Ground shaking map from the December 16, 1811, New Madrid earthquake. This quake rang church bells in Charleston, South Carolina, and was felt as far away as Maine and Canada. The earthquake is estimated to be between magnitude 7 and 8.

The Reelfoot Rift

The New Madrid seismic zone is bounded by a series of faults beneath the continental crust in a weak spot known as the Reelfoot rift. The fault system extends 150 miles southward from Cairo, Illinois, through New Madrid and Caruthersville, Missouri, down through Blytheville, Arkansas, to Marked Tree, Arkansas. It dips into Kentucky near Fulton and into Tennessee near Reelfoot Lake, extending southeast to Dyersburg, Tennessee. It crosses five State lines and crosses the Mississippi River in at least three places. The fault system is buried beneath as much as 5 miles of sediments for much of its length and typically cannot be seen at the surface. (Image modified from Braile and others, 1986.)





The New Madrid seismic zone is the most seismically active region in the United States east of the Rocky Mountains. Seismicity recorded between July 1974 and June 2003 is shown here, along with the inferred epicenters of the three largest 1811–1812 New Madrid earthquakes. Brown lines mark the east and west boundaries of the Reelfoot rift. The U-shaped outer purple line marks the edge of the Mississippi embayment.

Where Is the New Madrid Fault?

Unfortunately, you cannot easily put your finger on the New Madrid fault. One reason is because there is no single fault; instead, the earthquakes occur along a zone that likely comprises several faults (see figure, facing page). In addition, the faults in the seismic zone are deeply buried beneath miles of sediment of the Mississippi River Valley—there are very few places where these faults are exposed at the Earth's surface. This makes the New Madrid region harder to study than other well-known faults like the San Andreas in California.

Site of Past Great Earthquakes

The geologic record of earthquakes before 1811 reveals that over the past 4,500 years the New Madrid seismic zone has repeatedly produced sequences of major earthquakes, including several over magnitude 7. These prehistoric earthquakes caused severe and widespread ground failures in the New Madrid region, much like those caused by the 1811–1812 earthquake sequence, and produced one of the largest liquefaction fields in the world.

An Earthquake Today...

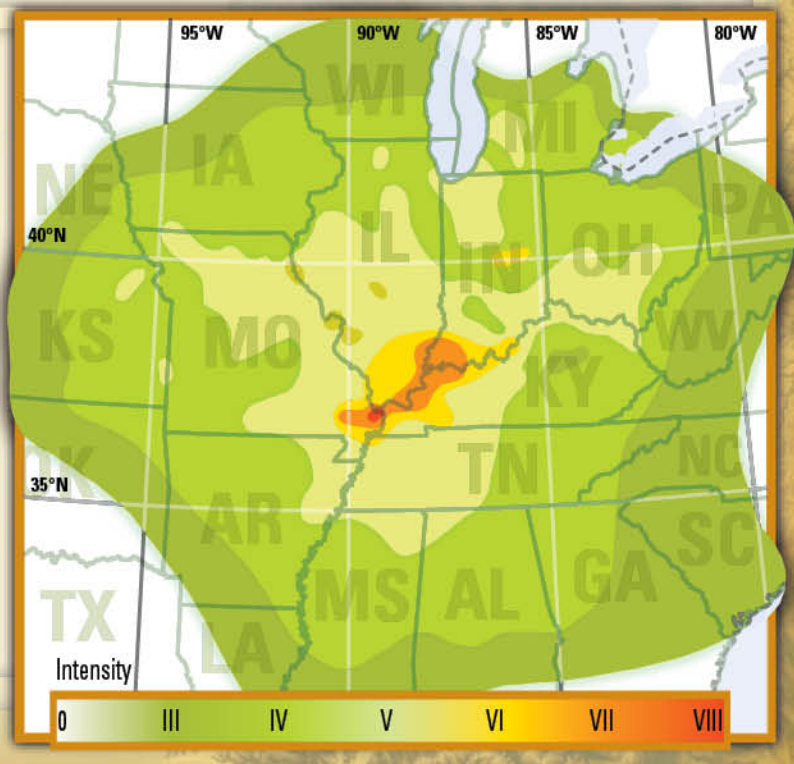
The Federal Emergency Management Agency commissioned the Mid-America Earthquake Center to estimate the combined effects throughout the region, should the New Madrid earthquakes of 1811–1812 repeat today. Their estimates (based on a 2 a.m. event of magnitude 7.7) include:

- An estimated 86,000 casualties might occur; fatalities would number about 3,500.
- Nearly 2,000,000 people would require short-term shelter on day 3 after the event.
- Total economic losses from damage to buildings, direct business interruption losses, and damage to transportation and utility systems could exceed $200-300 billion. Direct economic losses due to building damages (not including business interruption losses) are estimated to exceed $100 billion.
- Many fires would burn, primarily in areas around the epicenter and metropolitan areas. The lack of operational firefighting equipment and water due to the earthquake would be a major concern.
- About 50 percent of urban households in the highest impact areas would be deprived of water. It would take weeks, if not months, to restore the water systems to normal operation.
- Hospitals would likely suffer significant building damage that could result in up to 150 facilities being nonfunctional.
- More than 1,300 schools and more than 700 fire stations may have significant damage.
- Close to 3,500 highway bridges would be damaged, hampering recovery efforts.
- Approximately 2.6 million households would be without power.
- More than 50 million tons of debris would be generated.
- Approximately 715,000 buildings could be damaged.

[Information in this section taken from Central U.S. Earthquake Consortium (2010) and Elnashai and others (2009).]

The Charleston, Mo., Quake

This earthquake, located in the bootheel of Missouri, occurred on October 31, 1895, and had an estimated magnitude of 6.6. The quake caused extensive damage (including downed chimneys, cracked walls, shattered windows, and broken plaster) to school buildings, churches, private houses, and to almost all the buildings in the commercial section of Charleston. The shock was felt over all or portions of 24 States and in Canada.



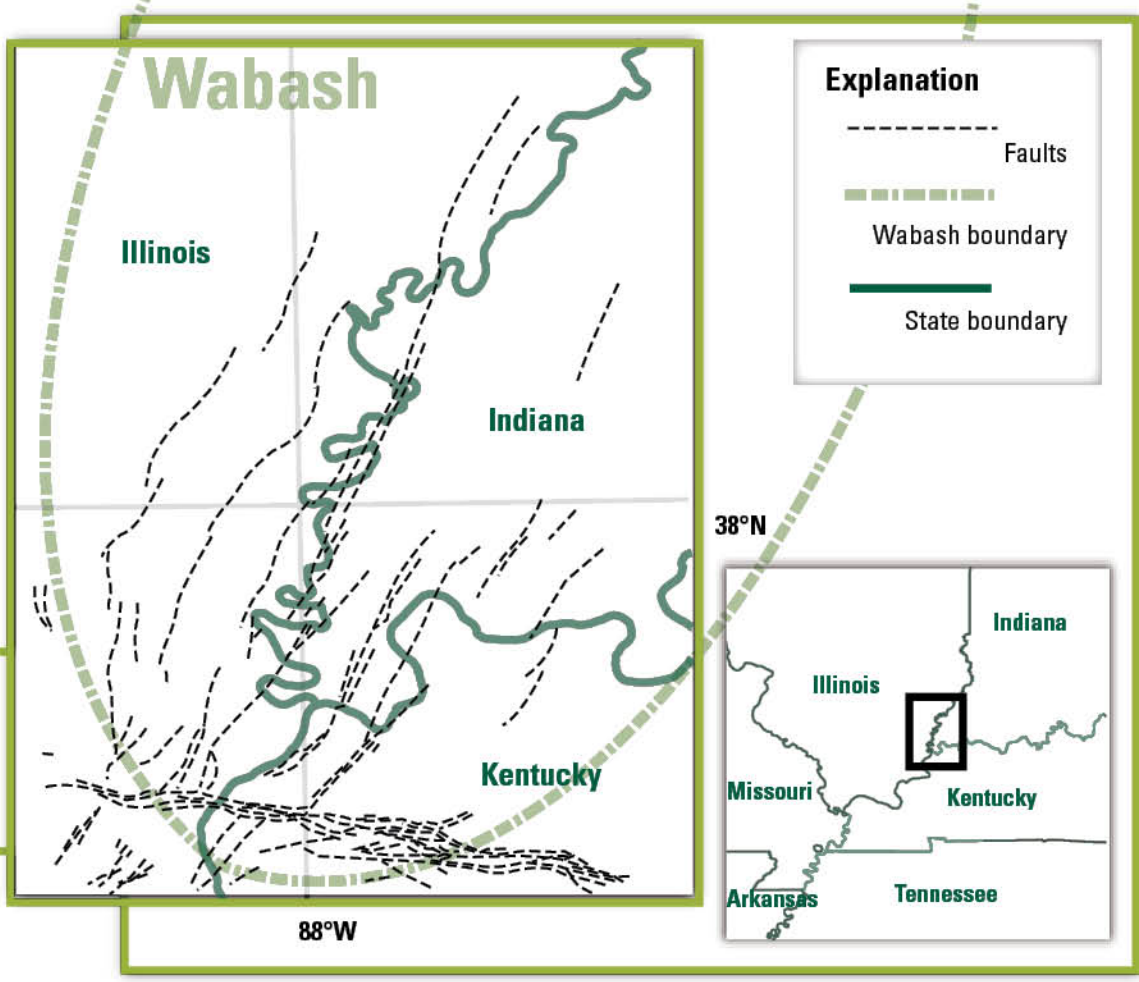
RIGHT—Ground-shaking intensity from the magnitude 6.6 (estimated) Charleston, Missouri, earthquake of 1895. The strongest shaking was recorded along the Ohio River Valley. The map is based on historical accounts of the earthquake. Roman numerals indicate measurement on the Modified Mecalli Intensity scale.

Wabash Valley Seismic Zone

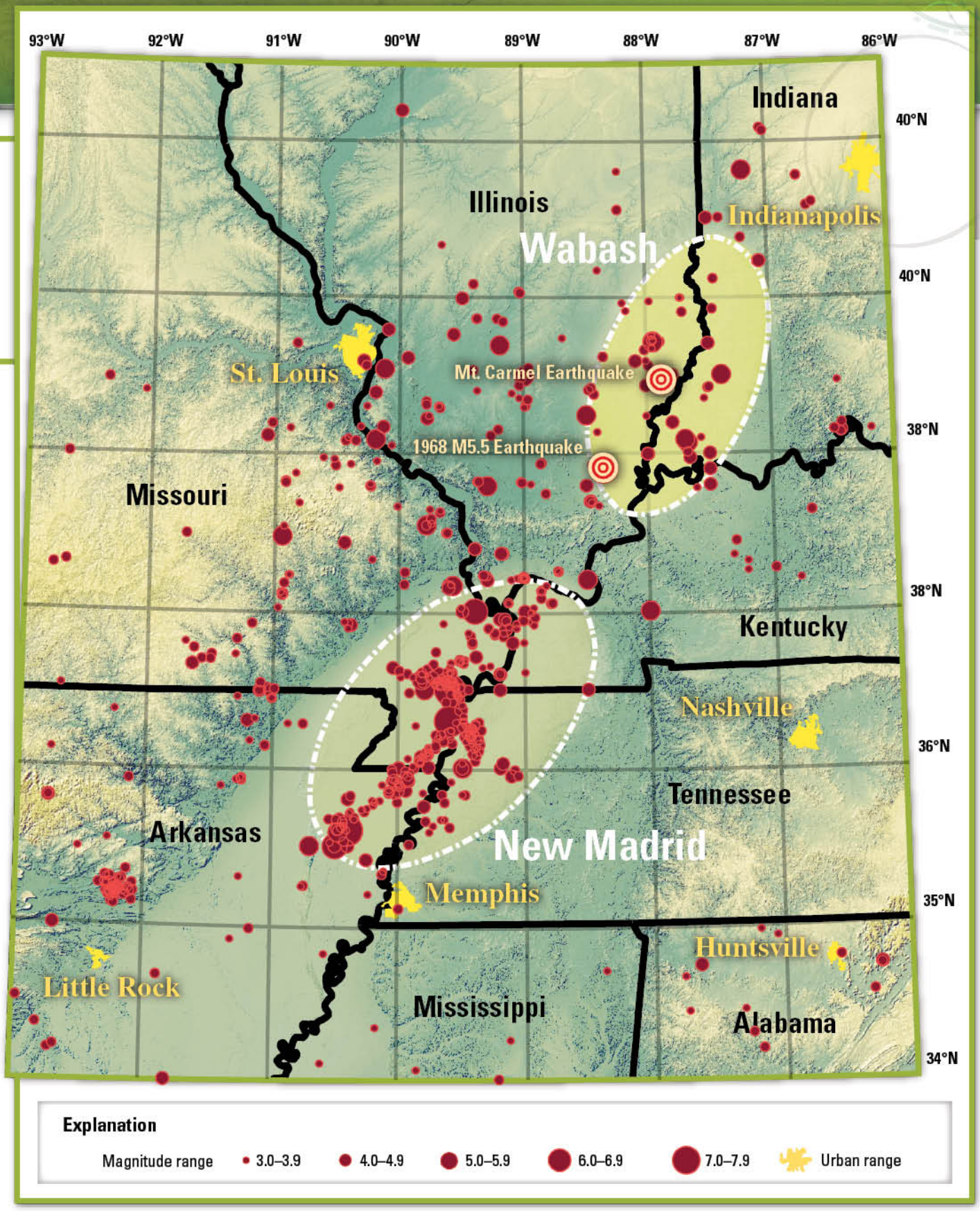
The faults of the Wabash Valley seismic zone are deeply buried under layers of sediment. Although the tectonics of the region are still not fully understood and are the subject of ongoing research, these faults are thought by some to be associated with a branch of the ancient Reelfoot rift, where the tectonic plate actively began to pull apart at perhaps two separate times in the distant past. The **crust** in the area has been weakened by the numerous faults, which remain active sites for continuing seismicity (see figure, below).

Based on geologic evidence, the Wabash Valley seismic zone has recorded at least eight prehistoric earthquakes over the past 20,000 years, with magnitudes ranging from 6.5 to 7.5. The two largest modern earthquakes were magnitude 5.5 and 5.4 temblors; the first occurred in 1968 and the second in 2008 (see figure, facing page).

The Wabash Valley seismic zone straddles the Indiana-Illinois State boundary and is characterized by a zone of active seismicity. The magnitude 5.4 Mt. Carmel earthquake occurred within the Wabash Valley seismic zone in 2008.



Fault map showing potential earthquake faults in the Wabash Valley seismic zone. (Modified from Wheeler, 1997.)


93°W
92°W
91°W
90°W
89°W
88°W
87°W
86°W
40°N
38°N
36°N
35°N
34°N
Indiana
Illinois
Indianapolis
Wabash
St. Louis
Mt. Carmel Earthquake
1968 M5.5 Earthquake
Missouri
Kentucky
Nashville
Tennessee
Arkansas
New Madrid
Memphis
Huntsville
Little Rock
Mississippi
Alabama
Explanation
Magnitude range
3.0–3.9
4.0–4.9
5.0–5.9
6.0–6.9
7.0–7.9
Urban range

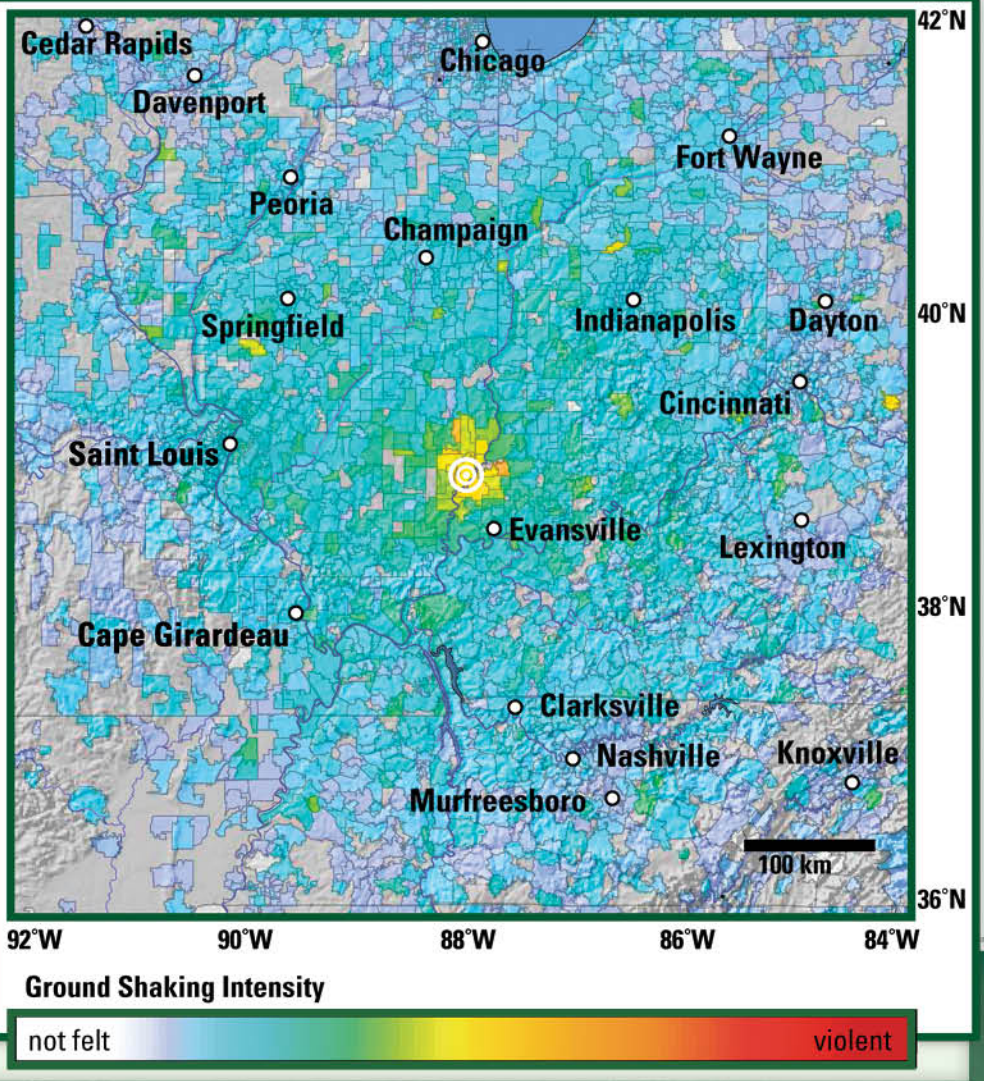
Most Earthquake Damage Is Caused by Shaking

The* intensity *of shaking that a building or structure will experience during an earthquake is highly variable, but it generally depends on three main factors:

- The distance from the earthquake—the closer to the source of the earthquake, the greater the shaking.
- The magnitude of the earthquake—the larger the quake, the stronger the shaking and the larger the affected area.
- The type of ground material beneath the structure—soils may amplify the shaking relative to hard bedrock.

Magnitude or Intensity

Magnitude is a measure of the size of an earthquake—a single value that depends on the area of fault rupture and amount of slip. For example, the 2008 Mt. Carmel, Ill., earthquake had a magnitude of 5.4. Intensity is a measure of damage caused by ground shaking at a particular place and varies by location, proximity to the source of the earthquake, and type of material underlying the site. The intensity scale ranges from "Not Felt" (I) to "Complete Destruction" (XII). Near the epicenter of the Mt. Carmel earthquake, the intensity reached VI; however, at Cape Girardeau over 100 miles away, intensity levels were about IV.



Ground shaking intensity from the magnitude 5.4 Mt. Carmel earthquake of 2008. Values are based on individual accounts entered into the U.S. Geological Survey online "Did You Feel It?" system. Over 37,000 entries were registered, extending from Canada down to Alabama.

BELOW Baldcypress trees in Reelfoot Lake, northwest Tennessee. Growth patterns in the trees show that the lake formed around 1811, confirming historical accounts of the 1811–1812 New Madrid earthquakes.
(Photo courtesy of Buddy Schweig, U.S. Geological Survey.)

Young growth along edges of sunk lands created during the New Madrid earthquakes of 1811–1812. Valley River, Missouri, 1904.
(Photo from Fuller, 1912.)

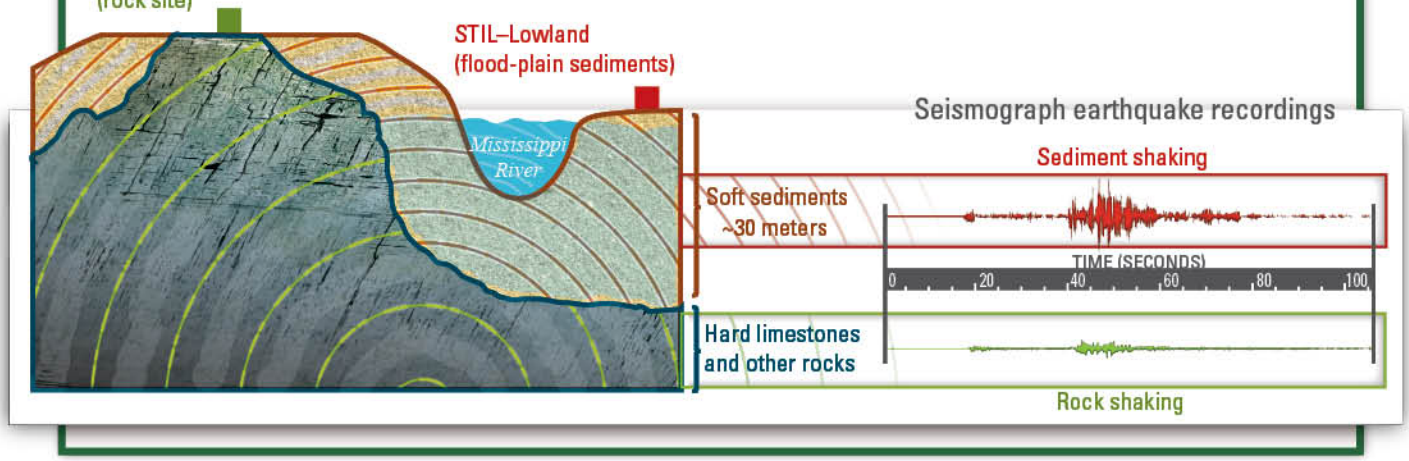
Soils Affect Ground Shaking

Earthquakes generate seismic waves at a wide variety of frequencies, and certain frequencies may be amplified by local soil conditions (see figure, below).

- Areas with thin sedimentary deposits, such as St. Louis, experience less severe amplification than areas with thick deposits.
- In areas with thick sedimentary deposits, such as Memphis, low-frequency seismic energy is amplified, yielding slow, rolling-type shaking that can damage tall buildings and long-span bridges and overpasses.
- Areas with thin, stiff (that is, sandy and gravelly) soil over bedrock amplify high-frequency seismic waves, which yield vigorous ground vibrations that cause more damage to short buildings (1–2 stories) such as houses.

Soft, thick sediments = more seismic shaking!

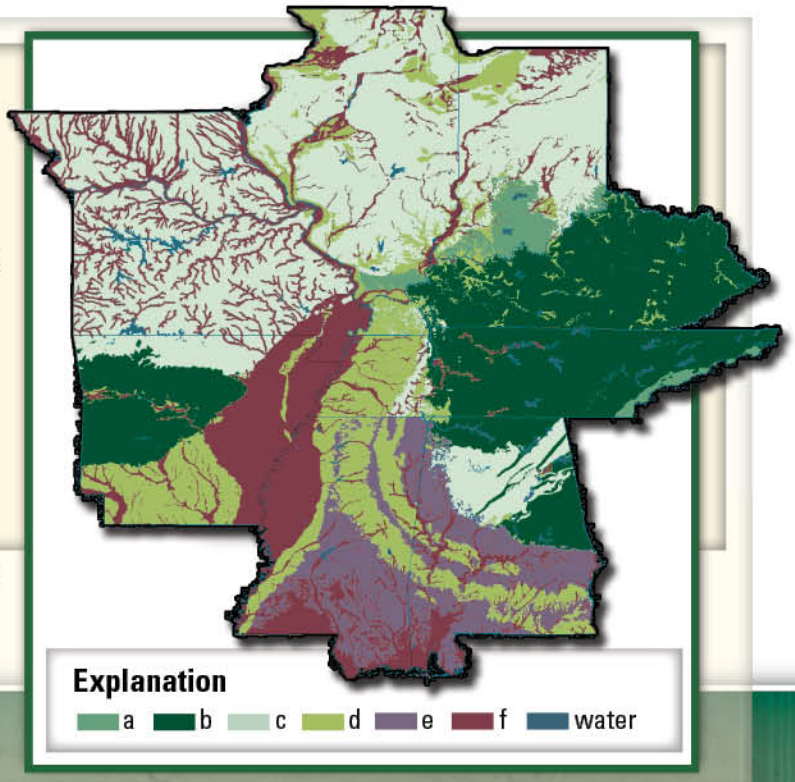
Generalized west-east cross section through the Mississippi River Valley showing the response to seismic waves generated during a New Madrid earthquake.



Central United States Soil Classes

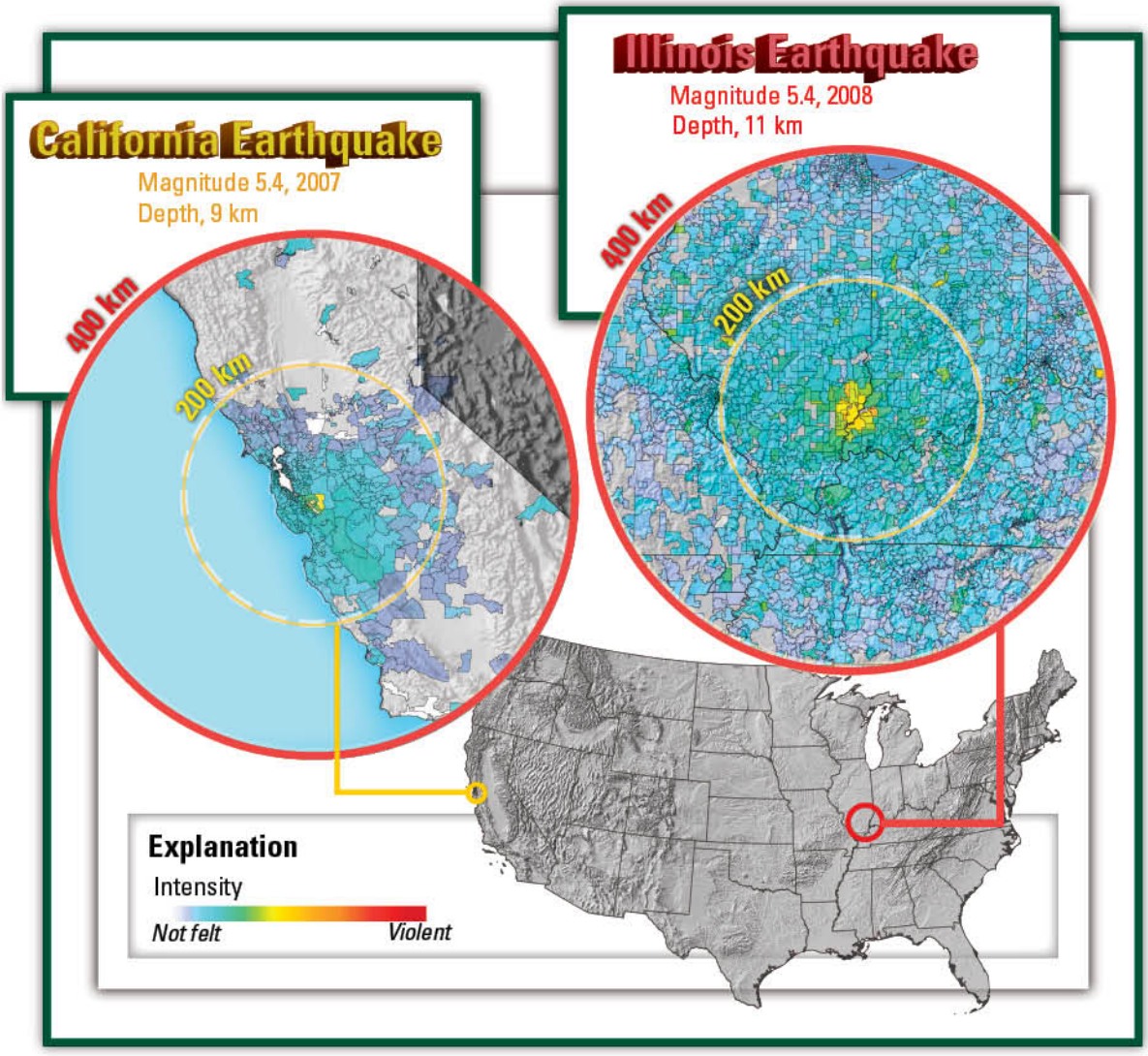
Soil site classes are categories based on attributes such as sediment thickness, underlying rock type, and depth to groundwater. These attributes influence shaking intensities during an earthquake. In the soil map depicted here, earthquake shaking is anticipated to be lowest for areas colored green (a) and highest for areas colored red (f). Classes a, b, and c usually have thinner soils and harder bedrock. Classes d and e have thicker soils and softer bedrock. Class f represents very thick soils or unconsolidated sediments, often with a high water table, subject to greater shaking and liquefaction.

[Modified from graphic contributed by the Association of Central U.S. Earthquake Consortium State Geologists.]



Decay of Seismic Energy with Distance

Amplitudes of earthquake waves die out as they move away from the **epicenter**. Wave energy decreases much more slowly in the Central and Eastern United States than in the West, so, for the same size earthquake, there is greater shaking over larger areas in the Eastern United States compared to the Western United States. This difference is demonstrated by two recent earthquakes of the same magnitude, one that occurred in Northern California and the other located in eastern Illinois (see figure, below). The California earthquake was felt over distances typically less than 200 km, while the Illinois earthquake was felt in excess of 400 km away.



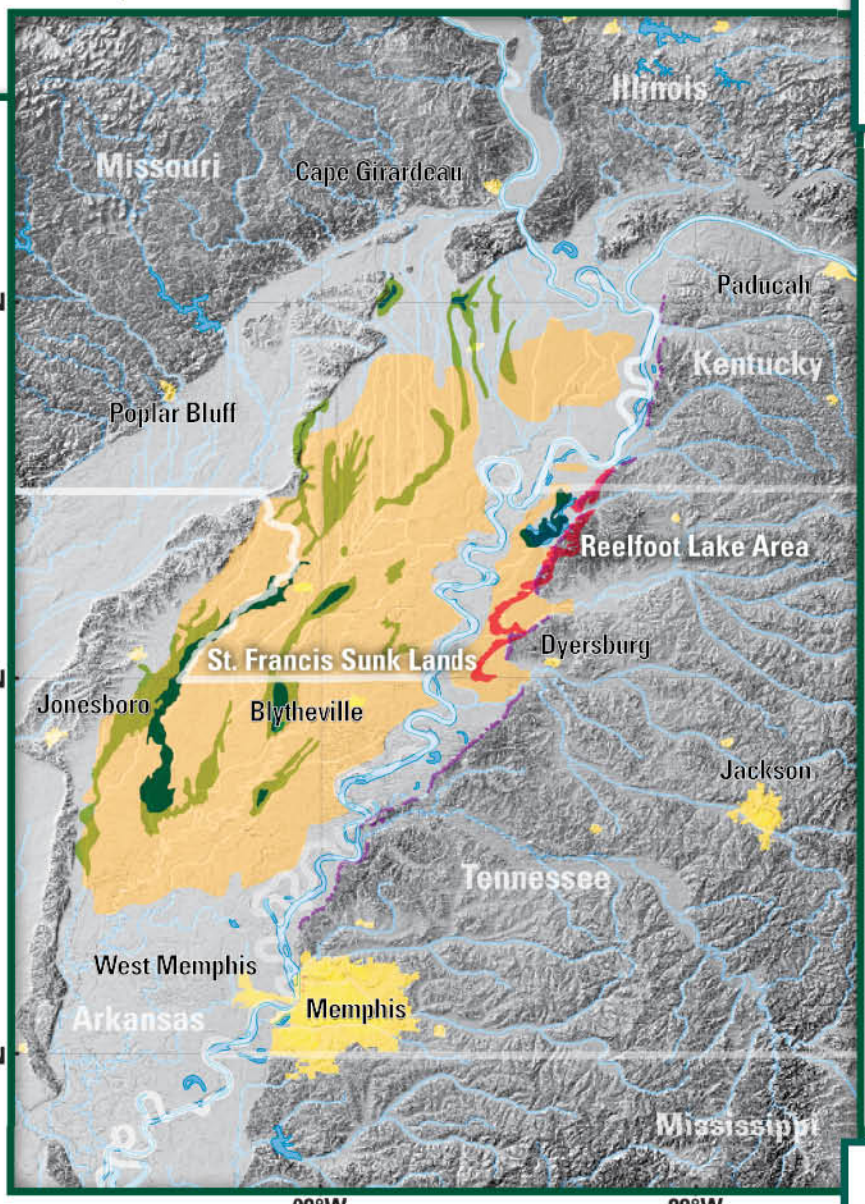
Intensity maps for two U.S. earthquakes. Left, Northern California earthquake representative of ground shaking of earthquakes in the Western United States. (Alum Rock, California; October 30, 2007.) Right, Eastern Illinois earthquake representative of ground shaking of earthquakes in the Central United States. (Mt. Carmel, Illinois; April 18, 2008.)

Effects of Shaking

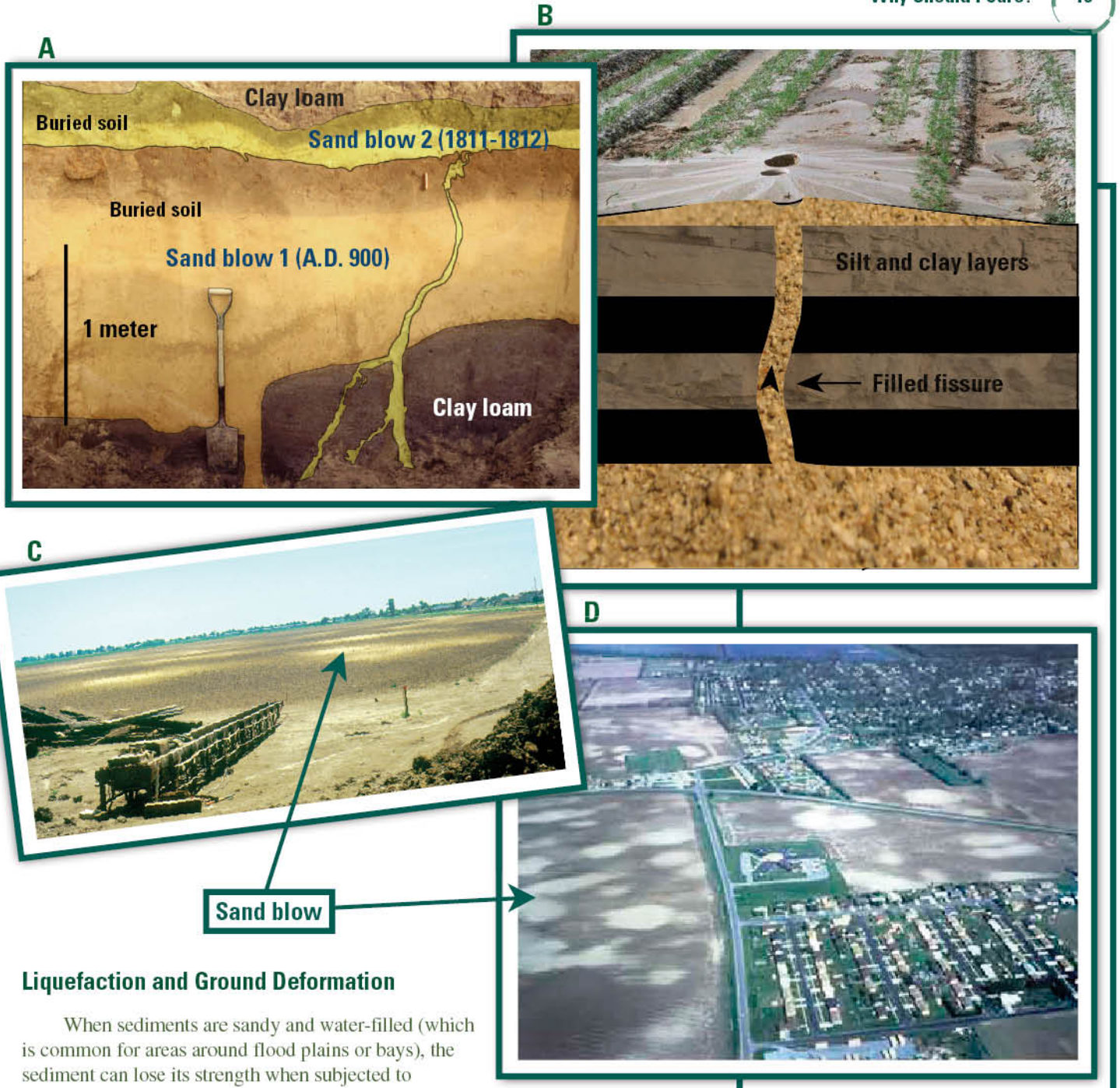
Extensive Ground Deformation

The ground shaking from the New Madrid earthquakes in 1811–1812 was strong enough to force sand to erupt at the surface, trigger landslides, and cause large areas to be uplifted or dropped down in elevation, creating sunk lands such as Reelfoot Lake that later filled with water (see figure, below). Large coherent block landslides have been mapped for over 80 km along the eastern bluffs at the edge of the Mississippi alluvial plain in western Tennessee and Kentucky (see photo, right). Areas of liquefaction and flooding of similar sizes have been mapped within the alluvial plain, along with areas of localized uplift and **subsidence**.

Landslide trench and ridge resulting from the New Madrid earthquake, Chickasaw Bluffs, Tennessee.
(Photo from Fuller, 1912.)



Map showing generalized geology, ground failures, and other disruptions of the ground surface in the epicentral region of the 1811–1812 New Madrid earthquakes. (Modified from Fuller, 1912, and Jibson and Keefer, 1988.)



Liquefaction and Ground Deformation

When sediments are sandy and water-filled (which is common for areas around flood plains or bays), the sediment can lose its strength when subjected to earthquake shaking. This process is known as liquefaction. Liquefaction often leads to over-pressured fluids that can erupt to the surface, forming features known as sand blows (see figure, above). Liquefaction along the Mississippi River Valley during the 1811–1812 earthquakes created one of the world's largest sand blow fields; evidence of these features is still visible today.

Large, widespread, and abundant prehistoric sand blows were produced over the same area during ground shaking from earthquakes that predate the 1811–1812 earthquakes. The sizes and areal distribution of the prehistoric sand blows indicate that the older earthquakes were similar in location and magnitude to the 1811–1812 shocks. Dating of these prehistoric structures indicates that these prehistoric earthquakes occurred around A.D. 1450, A.D. 900, and 2350 B.C.

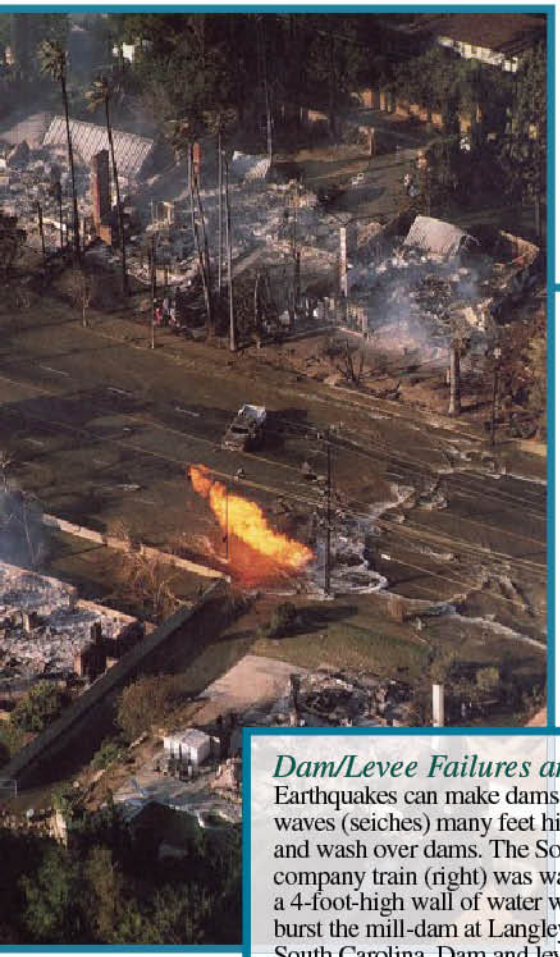
Photo examples of sand blows. A, Sand blows are the smoking guns that prove the occurrence of past large earthquakes. B, Sand blows eject liquefied sand to the surface, resulting in a cone-shaped mound. Many of these features created during the New Madrid earthquakes of 1811–1812 are still visible today. C, Sand erupted to the surface in Blytheville, Arkansas. D, Recent sand blows dot the landscape surrounding New Madrid, Missouri. (All photos courtesy of Buddy Schweig, U.S. Geological Survey.)

Earthquakes Cause Damage in Other Ways

Although most earthquake damage is caused by shaking, other damaging effects of earthquakes can be just as devastating.

Damaged Infrastructure—Earthquakes often damage roads and bridges, hindering rescue and recovery efforts and causing accidents. Water and sewer pipeline breaks can result in contamination of surface water and groundwater and can cause sinkholes that undermine roads and buildings. Damage to natural gas and electrical distribution systems can cause fires and major service outages. Damage to petroleum pipelines can cause oil spills. The photo to the left shows damage to Interstate 5 caused by the 1994 Northridge earthquake, California.

[Photo coutesy of the Federal Emergency Management Agency.]

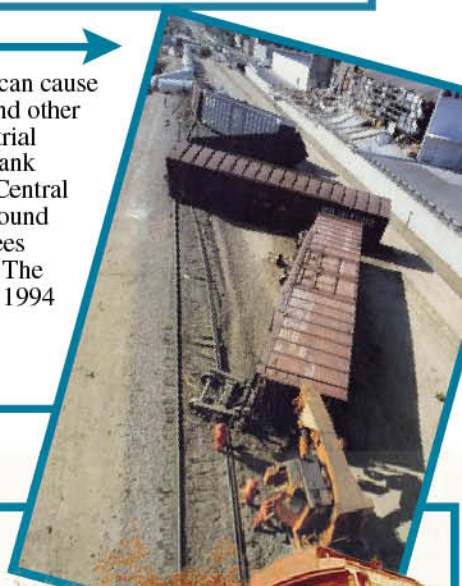


Fires—Earthquakes in urban areas are often followed by destructive fires because gas lines break, electrical shorts ignite fires, damaged water tanks and broken pipes limit water for firefighting, and clogged roads and collapsed bridges prevent access for firefighters. The photo to the left is an aerial view of Balboa Boulevard in Granada Hills, California, during the 1994 Northridge earthquake. The street has flooded, homes are burned, and a broken natural gas line has caused a fire to erupt.

[Photo by Lacey Atkins, *Los Angeles Times*.]

Hazardous Materials—Earthquake damage can cause releases of hazardous materials from refineries and other chemical storage and distribution systems, industrial laboratories, manufacturing plants, and railroad tank cars. This consequence is a great concern in the Central United States where failure of pipelines, underground storage facilities, or storage tanks on earthen levees could have serious environmental consequences. The photo to the right shows a train derailment in the 1994 Northridge, California, earthquake that released sulfuric acid from a tanker car.

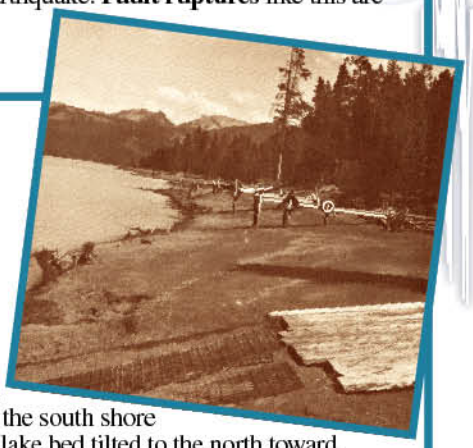
[Photo by Gail Fisher, *Los Angeles Times*.]



Dam/Levee Failures and Seiches—Earthquakes can make dams fail and generate waves (seiches) many feet high that flood shorelines and wash over dams. The South Carolina Railway company train (right) was washed from the track by a 4-foot-high wall of water when the 1886 earthquake burst the mill-dam at Langley Pond near Aiken, South Carolina. Dam and levee failure in the Central United States would cause regional flooding and impede navigation along the Mississippi River corridor.

[Photo by J.A. Palmer, South Caroliniana Library Archives, Aiken, S.C.]

Surface Fault Rupture—In a large earthquake, fault movement can break the ground surface, damaging buildings and other structures. In the photo to the left, a barn near Hebgen Lake in Montana was damaged by a **fault scarp** along the Red Canyon fault during the 1959 Hebgen Lake earthquake. **Fault ruptures** like this are likely on the Reelfoot fault.
[Photo published in Witkind (1962).]



Tectonic Uplift and Subsidence—Faulting due to compressive forces elevates rocks on the up-thrown side of the fault, while the down-thrown side of the fault undergoes tilting and subsidence. The photo to the right shows abandonment of the south shore of Hebgen Lake in the 1959 earthquake as the lake bed tilted to the north toward the fault. Existing lakes in the New Madrid region may be altered in a similar fashion.
[Photo published in Witkind (1962).]

Rockfall—One of the most common types of landslides caused by earthquakes are rockfalls, triggered by ground shaking in areas of rock outcrops or loose rocks on hillsides. The photo to the left shows the fresh cliff face following rockfalls triggered by the magnitude 7.0 earthquake in Haiti in 2010.
[Photo courtesy of Edwin Harp, U.S. Geological Survey.]

Lateral Spreading—During periods of extended seismic ground shaking, saturated soils near bays and rivers can lose their strength, sliding downhill toward the water, as seen in the photo above. During the 1811–1812 New Madrid earthquakes, lateral spreading produced extensive ground deformation along the banks of the Mississippi River.
[Photo courtesy of the Association of CUSEC State Geologists.]

Other Effects—Shaking from earthquakes can cause other damage to land as well, including the creation of fissures, the collapse of sinkholes, changes to groundwater levels, and flooding from liquefaction. The photos above and to the right show examples of fissures and sinkholes resulting from the 1997 and 2003 Alabama earthquakes of magnitudes 4.9 and 4.7, respectively.
[Photos courtesy of Dorothy Raymond, Geological Survey of Alabama.]

Response of Buildings to Earthquakes

Seismic provisions are defined in the 2009 edition of the International Building Code and are based on U.S. Geological Survey National Seismic Hazard assessments.

Much like trees swaying in the wind, buildings sway to the effects of earthquakes. Foundations connect structures to the ground, and they play a very important role in determining how much force a building can resist. Engineers study this critical interface and may choose to cushion the effect by using special foundation designs. Designing a structure to withstand earthquakes will also help protect the structure from tornadoes.

The soil underlying buildings is an important ingredient in determining the effects of earthquakes on structures.

- Soft, clayey soils tend to increase the motion at the ground surface and thereby amplify the effects on buildings and structures. Rock does not change the motion nearly as much as soil, so shaking is more predictable.
- A building's configuration and height also play an important role in determining the effects an earthquake will have on its performance. Square or rectangular buildings typically perform better than irregular-shaped buildings.
- Tall buildings respond by swaying back and forth. Short structures are jarred from side to side as the earthquake releases its force at the ground surface.

The materials from which a building is constructed help determine how it performs during an earthquake.

- Concrete and masonry are more inflexible and can transfer the ground motion directly into the structure. They crack when they deform.
- Steel and wood are considered flexible or ductile and tend to deform without breaking.

Earthquakes shake buildings from the ground up, and an important consideration for performance of materials during a quake is the length of time the ground shakes. The longer the ground shakes, the more likely the structure will be unable to resist the effects. Bigger earthquakes release their energy over a larger area and for a longer period of time, resulting in a longer shaking duration. Building materials can resist temporary overstress caused by shaking, but they will break when stretched beyond their limits, much like a paper clip that eventually breaks after being bent back and forth over and over.

A building's skeleton or structure is important for protecting the lives and safety of its occupants. The so-called nonstructural elements, however, can be very dangerous. Items such as bookcases, filing cabinets, shelves, ceiling tiles, and light fixtures often fall to the floor or hurtle across rooms during earthquakes, injuring and possibly killing occupants. Such problems can be anticipated and addressed before an earthquake. Just as buildings should be designed and braced for earthquakes, nonstructural components require similar consideration.

Virtually all structures are susceptible to damage from an earthquake. Dams, bridges, pipelines, storage tanks, and roadways are other structures that can be damaged by an earthquake's forces. These infrastructure elements are often taken for granted, and only after an earthquake are they viewed as critical components necessary for maintaining our standard of living. The infrastructure we rely upon can be fragile in ways we may not understand until after it is damaged or disabled in an earthquake.

Earthquake-resistant infrastructure is critical to minimizing economic loss and expediting response and recovery following a damaging earthquake. In the Central United States, numerous bridges, pipelines, and transmission lines are vulnerable to earthquake ground shaking. Strengthening of some of the most critical structures has already begun, such as these shock absorbers recently installed on the I-70 bridge across the Mississippi River in St. Louis. (Photo courtesy of Richard Steckel, St. Louis University, St. Louis, Mo.)

Unreinforced Masonry Buildings

One building type of particular concern in the Central United States is masonry constructed without steel reinforcement. Unreinforced masonry buildings were popular when the region was first settled, and construction of them continued into the 1970s. Many residences, as well as commercial buildings, are unreinforced masonry buildings and were constructed without knowledge of how these structures performed in earthquakes (see table, right). Unfortunately, experience now shows this is one of the most dangerous building types, and evidence of its poor performance in earthquakes throughout the world is well documented.

	Total unreinforced masonry structures (URM)	"Extensive" or "Complete" damage to URM[1]	Total buildings
Alabama	78,010	18	1,631,520
Arkansas	130,557	13,345	1,143,135
Kentucky	137,881	167,881	1,338,371
Indiana	358,701	13,345	1,882,179
Mississippi	56,139	2,300	1,017,335
Missouri	379,495	15,615	1,770,545
Illinois	689,709	5,293	3,251,213
Indiana	358,701	111	1,932,056
Tennessee	194,971	40,502	2,077,186
Total	2,384,164	258,410	16,043,540

[1] Based on a magnitude 7.7 earthquake equivalent to the New Madrid events of 1811–1812.

Unreinforced masonry building inventory and seismic vulnerability in the Central United States. From Elnashai and others (2008).

The ABCs of Seismic Building Codes

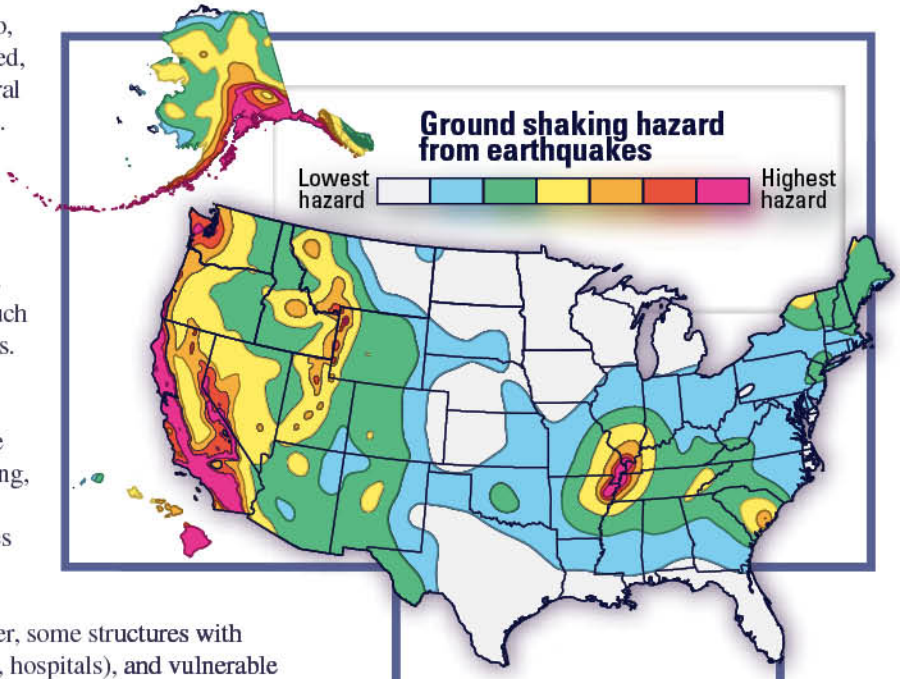
Seismic building codes increase building integrity and help ensure the future safety of communities. These codes are designed to protect lives, not to ensure buildings remain undamaged or usable after an earthquake. Seismic codes are intended to protect people inside buildings by preventing collapse and allowing safe evacuation. Structures built according to the International Building Code (see photo, facing page) should resist minor earthquakes undamaged, resist moderate earthquakes without significant structural damage, and resist severe earthquakes without collapse.

A moderate earthquake that does not significantly damage a building still can seriously hurt or kill people. Buildings contain items such as light fixtures, heating ducts, windows, and suspended ceilings that can fall on people or block escape routes. The exteriors of buildings also can pose hazards to people walking by or exiting, such as falling bricks, parapets, window glass, or other facades.

Steel-frame tall buildings and newer wood-frame short buildings are usually (but not always) the safest structure types. Exceptions to these generalizations are due to variables such as the configuration of the building, the quality of construction and inspection, the design of connections, and the manner in which seismic waves strike a particular site.

Building codes provide minimum design and construction requirements for protecting lives. However, some structures with high occupancy, critical-response services (fire, police, hospitals), and vulnerable populations (schools, nursing homes) should be built above minimum requirements; building codes use importance factors for designing above these minimum requirements. It also is important to protect utilities and infrastructure (see photo, facing page, bottom) since damage to these critical structures leads to more deaths, larger economic loss, greater social disruption, and slower response to earthquakes.

The seismic provisions of building codes are based on earthquake hazard maps (see figure, right) that show the probabilities of certain levels of earthquake shaking in particular areas. The code requirements reflect the fact that some places are more likely than others to have strong earthquakes. The Central United States has areas of high seismic hazard, similar to States along the West Coast. Although large earthquakes are less common in this part of the country, the ground shaking effects are more significant than in the West.



U.S. Geological Survey National Seismic Hazard Map showing expected levels of strong earthquake shaking likely to occur within the next 50 years. Red colors define areas where ground shaking is expected to be strongest, while white colors are areas where ground shaking is likely to be minimal. (Map updated in 2008.)

Your Life Could Change Unexpectedly in the Next Quake

Where will your family be?

- Your children may be at school, day care, or other activities.
- Family members may be at work or commuting.
- Pets may run away or be injured.

Failure of fluorescent light fixtures in the Dawson Elementary School library during the 1983 Coalinga, California, earthquake. (Photo courtesy of the Earthquake Engineering Research Institute.)

Pets are not allowed in most emergency shelters. Do you have a plan to feed and care for your animals after an earthquake?

Will you have medical services?

- The 911 emergency system will likely be overloaded.
- Hospitals and other medical facilities may be damaged.
- Emergency rooms and trauma centers may be overwhelmed.
- Assisted living, critical care, and other health services such as dialysis may not be operational.

This hospital in Sylmar, California, had to be demolished after the magnitude 6.6 San Fernando earthquake of 1971. (Photo by R. Kachadoorian; from the U.S. Geological Survey Photographic Library.)

The magnitude 6.9 Loma Prieta earthquake in 1989 caused this section of the San Francisco–Oakland Bay Bridge to collapse. (Photo published in Nakata and others, 1990, slide II-1; from the U.S. Geological Survey C.E. Meyer collection.)

Will you be able to get home?

- Road damage and closures may restrict your ability to travel by car.
- Public transportation including buses, trains, and airports may experience closures or interruptions in service.
- Commute times may be dramatically increased.

Will you be able to stay in your home?

- Your home may be damaged and unsafe to live in.
- Your personal property may be damaged or destroyed.
- Construction materials and labor for repairs will be in limited supply and costs will increase.
- Rebuilding scams may be common.
- Availability of rental housing may be limited because of residential damage and high demand.

This porch on a wood frame house failed during the magnitude 6.9 Loma Prieta earthquake of 1989. The red tag indicates that this home is unsafe and must not be entered or occupied.
(Photo published in Nakata and others, 1990, slide VIII-7; from the U.S. Geological Survey H.G. Wilshire collection.)

Can you live without the services you rely on?

- Water may be in short supply.
- Natural gas and electric power may be out for days or weeks.
- Garbage and sewage services may be interrupted.
- Telephone, Internet, cell phone, and wireless communications may be overloaded or unavailable.
- Mail service may be disrupted or delayed.
- Gasoline may be in short supply, and rationing may be necessary.
- Bank operations may be disrupted, limiting access to cash, ATMs, or online banking.
- Grocery, drug, and other retail stores may be closed or unable to restock shelves.

Where will you get your water, food, medicines, and gasoline after an earthquake?

How will your job be affected?

- Businesses may sustain damage and disruption—many small businesses will require a long time to reopen. Some may not recover.
- Your income may be affected—payroll checks or direct deposits may be delayed.
- Your workplace may become a temporary shelter for you or others.
- Supplies and deliveries will be interrupted.

This business in Santa Cruz, California, was nearly destroyed in the magnitude 6.9 Loma Prieta earthquake of 1989.
(Photo published in Nakata and others, 1990, slide XIII-7; from the U.S. Geological Survey C.E. Meyer collection.)

American Red Cross

How will the American Red Cross help?

After a damaging earthquake, the American Red Cross will help in the following ways:

- Opening and operating emergency shelters.
- Assisting with the immediate mental-health needs of those affected.
- Providing blood and blood products.
- Obtaining and delivering other needed items such as water, baby supplies, and blankets.
- Providing food at shelters and feeding locations and through mobile distribution.
- Providing for basic health needs at shelters and other locations.
- Helping with initial recovery through casework and referrals to other agencies and partners.

For more information go to: *http://www.redcross.org/*

Your Financial Situation Could Be Affected by a Quake

Aid may not be available immediately following a major disaster. Without proper planning, the financial repercussions of an earthquake felt by you and your family could be devastating. Although many things are out of your control after a quake, your ability to recover financially depends on a number of factors that you can control. Prepare and follow a financial disaster recovery plan and you will be more likely to recover successfully. Consider the following:

This home in the Santa Cruz Mountains collapsed in the 1989 Loma Prieta earthquake.
(Photo published in Nakata and others, 1990, slide XI-2; from the U.S. Geological Survey J.K. Nakata collection.)

Will you be able to recover financially?

- You are still responsible for your existing debts, such as mortgages, leases, car payments, and credit card payments.
- You may not have access to important financial records.
- Your assets are at risk without sufficient earthquake insurance.
- If you have earthquake insurance and experience loss, begin working with your insurer to file a claim as quickly as possible.

Will you have money, food, and medicine?

- Bank operations may be disrupted, limiting access to cash, ATMs, or online banking.
- Food, drug, and other retail stores where you shop may be closed or unable to restock shelves.

This store was temporarily closed following the magnitude 6.8 Nisqually, Washington, earthquake in 2001.
(Photo courtesy of *The Olympian*, Olympia, Wash.)

This bank was damaged in the magnitude 6.8 Nisqually, Washington, earthquake in 2001, requiring customers to seek services elsewhere.
(Photo courtesy of *The Olympian*, Olympia, Wash.)

Will your insurance cover your losses?

- Homeowner's and renter's insurance policies do not cover losses related to earthquakes.
- A separate earthquake insurance policy is one way to help protect your home in addition to seismic retrofitting.
- Earthquake insurance also helps with living expenses in the days and weeks after an earthquake.
- Relatively few homeowners in the Central United States have earthquake insurance.

Does your small business have a recovery plan?

- A business disaster-recovery plan will make your business better able to survive in a post-disaster environment.
- Although physical assets can be replaced, emotional and social changes that affect businesses and their customers may remain long after a disaster.
- Businesses may not return to their previous revenue levels after a disaster; however, some businesses such as construction are likely to be in great demand following an earthquake.

Don't be Fooled!

Earthquake Myth—"Homeowner's insurance will cover any damage to my home or belongings caused by an earthquake."

Most residential property insurance policies do not cover damage resulting from earthquakes. A separate earthquake insurance policy is one way to protect your home and the investments you have made in personal belongings. Investigate your options carefully to ensure that your assets are sufficiently protected.

What types of Federal assistance may be available?

- Federal disaster-relief programs are designed to help you get partly back on your feet, but they are not meant to replace everything you lose.
- The Department of Homeland Security's Federal Emergency Management Agency (FEMA) is responsible for responding to, planning for, and reducing the effects of disasters.
- After the President signs a major disaster declaration, FEMA cooperates with other agencies, such as the Small Business Administration (SBA), in providing disaster relief.
- For disaster relief, low-interest loans are made available through the SBA to eligible individuals, homeowners, and businesses to repair or replace damaged property and personal belongings not covered by insurance.
- The maximum SBA personal-property loan is $40,000, and the maximum SBA real-property loan for primary home repair is $200,000.
- FEMA disaster grants for emergency home repairs and temporary rental assistance are available to individuals and households.
- The average FEMA grant is less than $15,000 (the maximum is $28,800)—not enough to rebuild a home.
- The Farm Service Agency offers loans to assist agricultural businesses.

Useful Web Sites—Ready Your Business

- Federal Emergency Management Agency—Are You Ready?
  http://www.fema.gov/areyouready/earthquakes.shtm
- Putting Down Roots in Earthquake Country—7 Steps to an Earthquake Resilient Business
  http://www.earthquakecountry.info/roots/7StepsBusiness2008.pdf
- QuakeSmart—Your Business, Your Investment, Your Choice
  http://www.quakesmart.org
- Ready.gov— Ready Business: Prepare. Plan. Stay Informed.
  http://www.ready.gov/business/

These small businesses in Santa Cruz, California, were heavily damaged in the magnitude 6.9 Loma Prieta earthquake of 1989, but both eventually reopened.
(Photo published in Nakata and others, 1990, slide XIII-3; from the U.S. Geological Survey C.E. Meyer collection.)

The Seven Steps to Earthquake Safety

Earthquakes are inevitable **in the Central United States, but earthquake damage can be reduced. Steps you can take before, during, and after earthquakes will help make you and your family safer and reduce injuries, damage, and losses:**

- First and foremost, plan for the personal safety of you and your loved ones.
- Look into the safety of your home, workplace, and child's school—don't be afraid to ask your landlord, boss, or school's principal if they are aware of the hazards and have taken measures to make these places safer and more earthquake resistant.
- Find out if your home, workplace, and child's school could be subjected to secondary seismic hazards such as landslides or liquefaction in addition to strong shaking.
- Don't forget to think about likely economic repercussions for you and your family from a major earthquake (see pages 22, 23, and 40).

The seven steps described in this section will help you to be safer during earthquakes. They are arranged as measures you should take before, during, and after quakes. These steps should be followed at home as well as at schools and workplaces. If everyone makes an effort to follow these steps, billions of dollars could be saved, injuries avoided, and many deaths averted in the next big earthquake.

You've learned your earthquake hazards, now follow these seven steps:

BEFORE A QUAKE

STEP 1: Identify potential hazards inside your home and begin to fix them. (page 26)

STEP 2: Create a disaster-preparedness plan. (page 28)

STEP 3: Prepare disaster supply kits. (page 30)

STEP 4: Identify your building's potential weaknesses and begin to fix them. (page 32)

DURING A QUAKE

STEP 5: Protect yourself during earthquake shaking. (page 34)

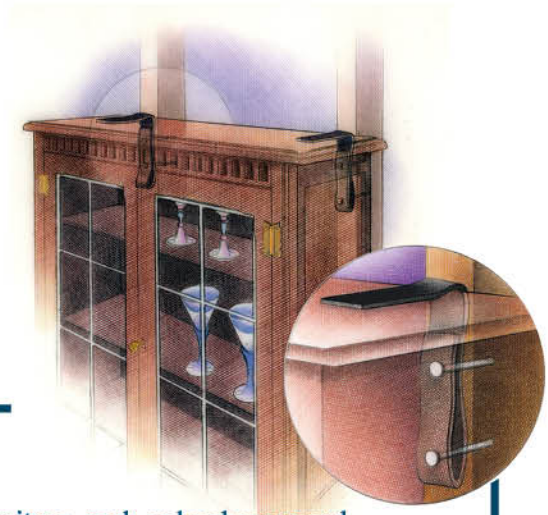
AFTER A QUAKE

STEP 6: After the earthquake, check for injuries and damage. (page 36)

STEP 7: When safe, continue to follow your disaster-preparedness plan. (page 38)

Step 1 Identify Potential Hazards in Your Home

The first step **to earthquake safety is to look around your home and identify all unsecured objects that might fall during shaking. START NOW by moving heavy furniture such as bookcases away from beds, couches, and other places where people sit or sleep. Also make sure that exit paths are clear of clutter.**



Simple and inexpensive things that you can do now will help reduce injuries and protect belongings in a quake. Many hardware and home-improvement stores carry earthquake safety straps, fasteners, and adhesives that you can easily use to secure your belongings.

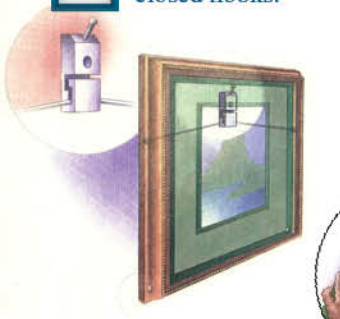
The following tips describe simple solutions to situations in your home that could be dangerous during earthquake shaking. If these have not yet been done in your home, ***take action now.***

X—Check the boxes!

Hanging objects

Art and other heavy objects hung on walls may fall, and glass in pictures and mirrors may shatter.

- ☐ Place only soft art, such as unframed posters or rugs and tapestries, above beds or sofas.
- ☐ Hang mirrors, pictures, and other hanging objects on closed hooks.



Objects on open shelves and tabletops

Collectibles and other loose objects can become dangerous projectiles.

- ☐ Hold collectibles, pottery, and lamps in place by using removable earthquake putty, museum wax, or earthquake gel.

Furniture

Tall, top-heavy furniture, such as bookcases and entertainment centers, may fall and injure you.

- ☐ Store heavy items and breakables on lower shelves.
- ☐ Secure both top corners of tall furniture into a wall stud, not just to the drywall.
- ☐ Flexible-mount fasteners, such as nylon straps, allow furniture independent movement from the wall, reducing strain on studs.

Water and gas pipes

Water or gas pipes anywhere in your home can break. Water leaks can cause extensive damage, and gas leaks are a major fire hazard.

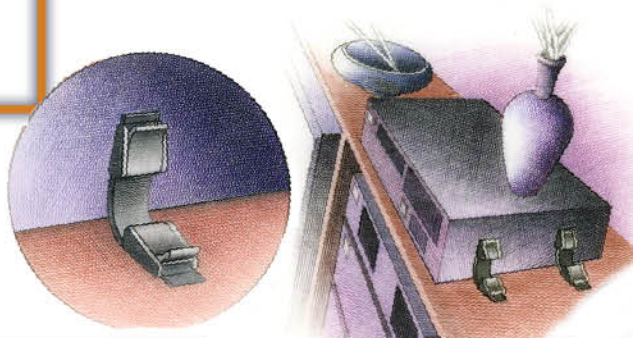
- ☐ Have a plumber evaluate, replace, and properly secure rusted or worn water and gas pipes.
- ☐ If not already done, have a plumber replace rigid gas connections to water heaters, stoves, dryers, and other gas appliances with flexible (corrugated) stainless-steel gas connectors (see illustration, facing page).
- ☐ Excess-flow gas-shutoff valves for individual appliances, which stop gas flow in case of a catastrophic leak, are also now available for use with flexible connectors.

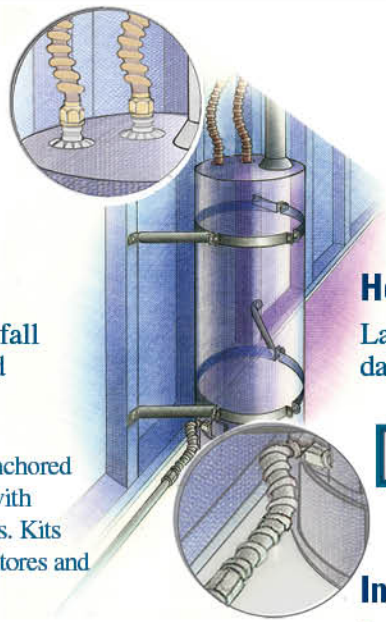
BEFORE A QUAKE

Don't be Fooled!

Earthquake Myth—
"Quake injuries are all from collapsing buildings."

Many people think that all injuries in earthquakes are caused by collapsing buildings. Actually, most injuries in quakes are from objects that break or fall on people. For example, in the magnitude 6.7 Northridge earthquake in 1994, 55 percent of quake-related injuries were caused by falling objects, such as televisions, pictures and mirrors, and heavy light fixtures.





X—Check the boxes!

Water heaters

Unsecured water heaters may fall over, rupturing rigid water and gas connections.

- ☐ Water heaters should be anchored to wall studs or masonry with metal straps and lag screws. Kits are available at hardware stores and home centers.
- ☐ If not already done, have a plumber install flexible (corrugated) copper water connectors.

In the kitchen

Glassware and china may crash to the floor if cabinet doors are unsecured. Gas appliances can shift, rupturing their gas connections.

- ☐ Secure all cabinet doors, especially those overhead, to help prevent contents from falling out during earthquakes. Use latches designed for child-proofing or earthquake or boat safety.
- ☐ Secure refrigerators and other major appliances to walls using earthquake appliance straps.

Home electronics

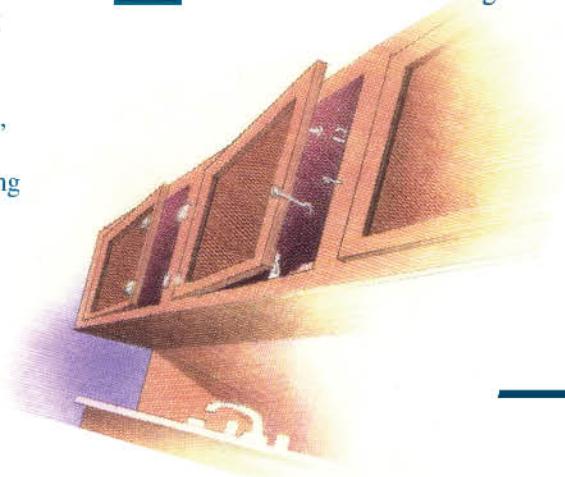
Large electronic devices may fall, causing injuries and damage. They are also costly to replace.

- ☐ Secure televisions, stereos, computers, and microwave ovens with flexible nylon straps and buckles for easy removal and relocation.

In the garage or utility room

Items stored in garages and utility rooms can fall, causing injuries, damage, and hazardous spills or leaks.

- ☐ Move flammable or hazardous materials to low areas that are secure.
- ☐ Ensure that items stored above or beside vehicles cannot fall and cause damage.



Step 2 Create a Disaster Preparedness Plan

Will everyone in your household know how to react during and after strong earthquake shaking? To be ready for the quakes that are certain to happen in the Central United States, it is important that your family have a disaster preparedness plan. Hold occasional earthquake drills to practice your plan. Share your disaster plan with your neighbors and discuss key points with babysitters, house sitters, and house guests. Your plan should include most of the following steps.

X—Check the boxes!

Plan NOW to Be Safe During an Earthquake

In a strong earthquake, individual survival skills will be crucial:

- ☐ Practice "DROP, COVER, AND HOLD ON." (See STEP 5, page 34)
- ☐ Identify safe spots in every room, such as under sturdy desks and tables.
- ☐ Learn how to protect yourself no matter where you are when an earthquake strikes. (See STEP 5, page 34)

Plan NOW to Respond After an Earthquake

Doing the following will enable you to help your family and others after a strong earthquake:

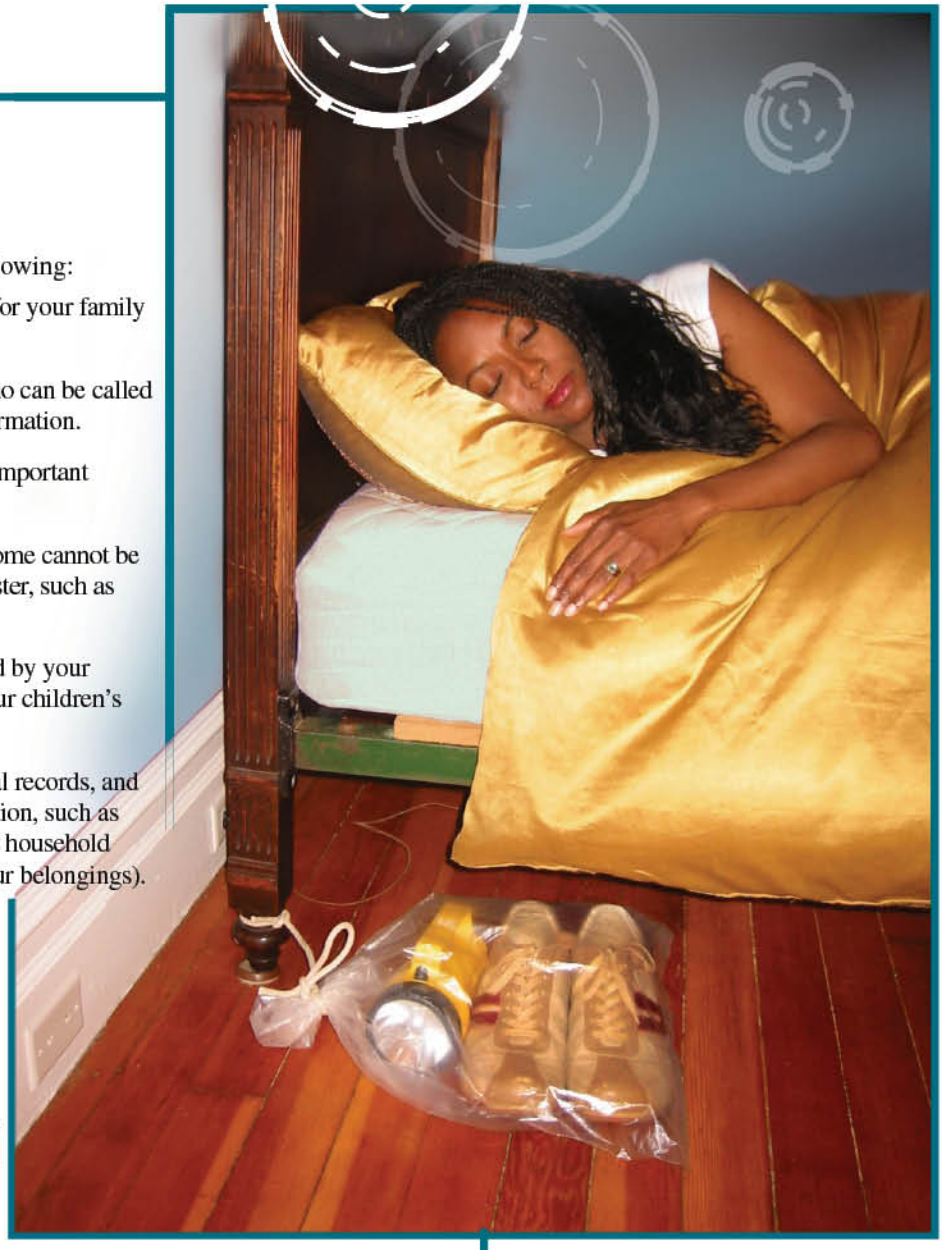
- ☐ Keep shoes and a working flashlight next to each bed.
- ☐ Teach everyone in your household to use emergency whistles or to knock three times repeatedly if trapped. Rescuers searching collapsed buildings will be listening for sounds.
- ☐ Identify the needs of household members and neighbors with special requirements or situations, such as use of a wheelchair or walking aids, special diets, or medication.
- ☐ Take a Red Cross first aid and CPR (cardiopulmonary resuscitation) training course. Learn who in your neighborhood is trained in first aid and CPR.
- ☐ Know the locations of utility shutoffs and keep necessary tools nearby. Know how to turn off the gas, water, and electricity to your home. Only turn off the gas if you smell or hear leaking gas. (See STEP 6, page 36)
- ☐ Get training from your local fire department in how to properly use a fire extinguisher.
- ☐ Install smoke alarms and test them monthly. Change the battery once a year or if the alarm emits a chirping sound (low-battery signal).
- ☐ Check with your fire department to see if there is a Community Emergency Response Team (CERT) in your area. If not, ask how to start one.

BEFORE A QUAKE

Plan NOW to Communicate and Recover After an Earthquake

Don't wait until the next earthquake to do the following:

- ☐ Locate a safe place outside of your home for your family to meet after the shaking stops.
- ☐ Establish an out-of-area contact person who can be called by everyone in the household to relay information.
- ☐ Provide all family members with a list of important contact phone numbers.
- ☐ Determine where you might live if your home cannot be occupied after an earthquake or other disaster, such as with friends or relatives.
- ☐ Learn about the earthquake plan developed by your children's school or day care, and keep your children's school emergency release cards current.
- ☐ Keep copies of insurance policies, financial records, and other essential documents in a secure location, such as with your household disaster kit. Include a household inventory (a list and photos or video of your belongings).



Your family may be sleeping when the next strong earthquake hits. After the shaking stops, the lights may be out and broken glass and other dangerous debris may litter the floor, making it unsafe to walk barefoot. Keep a flashlight and a pair of sturdy shoes secured to or within reach of everyone's bed. A good way to do this is to use a drawstring bag tied to a bedpost at the head of the bed for each occupant.

Step 3 Prepare Disaster Supply Kits

Personal Disaster Kits

Everyone in your family should have their own personal disaster kit. These kits are collections of supplies they may need when an earthquake strikes. Personalize these kits and keep them where they can easily be reached—at home, in the car, at work or school. A backpack or other small bag is best for these kits so that they can be easily carried in an evacuation. Include the following items:

- ☐ Medications, a list of prescriptions, copies of medical insurance cards, doctors' names and contact information.
- ☐ Medical consent forms for dependents.
- ☐ First aid kit and handbook.
- ☐ Spare eyeglasses, personal hygiene supplies, and sturdy shoes.
- ☐ Bottled water.
- ☐ Whistle (to alert rescuers to your location).
- ☐ Emergency cash.
- ☐ Personal identification.
- ☐ List of emergency contact phone numbers.
- ☐ Snack foods high in calories.
- ☐ Emergency lighting—light sticks and (or) a working flashlight with extra batteries and light bulbs (hand-powered flashlights are also available).
- ☐ Comfort items such as games, crayons, writing materials, and teddy bears.

Household Disaster Kit

Electricity, water, transportation, and other vital systems can be disrupted for several days or more after a large earthquake. Emergency response agencies and hospitals will likely be overwhelmed and unable to provide you with immediate assistance.

To help your family cope after a strong earthquake, store a household disaster kit in an easily accessible and safe location. This kit, which complements your personal disaster kits, should be in a large portable watertight container and should hold at least a 3- to 5-day supply of the following items:

- ☐ Drinking water (minimum one gallon per person per day).
- ☐ First aid supplies, medications, and essential hygiene items such as soap, toothpaste, and toilet paper.
- ☐ Emergency lighting—light sticks and (or) a working flashlight with extra batteries and light bulbs (hand-powered flashlights are also available).
- ☐ A hand-cranked or battery-operated radio (and spare batteries).
- ☐ Canned and packaged foods and cooking utensils, including a manual can opener.
- ☐ Items to protect you from the elements, such as warm clothing, sturdy shoes, extra socks, blankets, and perhaps even a tent.
- ☐ Heavy-duty plastic bags for waste and to serve other uses (tarps, rain ponchos, etc.).
- ☐ Work gloves and protective goggles.
- ☐ Pet food and pet restraints.
- ☐ Copies of vital documents, such as insurance policies and personal identification.

Note: Replace perishable items like water, food, medications, and batteries on a yearly basis.

For more information on safety, preparedness, and disaster kits, go to:

- The front section of your local telephone book
- Your local electricity and gas company Web sites
- Ready America—*http://www.ready.gov/america/*

BEFORE A QUAKE

A Special Note about Children

Before the next earthquake, spend time with your kids to discuss what might occur. Involve them in developing your disaster plan, preparing disaster kits (ask them what game or toy they want to include), and practicing **"DROP, COVER, AND HOLD ON."**

In the days after a quake, kids need extra contact and support. They may be frightened and under great stress, and aftershocks won't let them forget the experience. Parents may have to leave children with others in order to deal with the emergency, and this can be scary. Whenever possible, include your children in the earthquake recovery process.

Resources for kids to learn about disaster preparedness:

http://www.fema.gov/kids/

http://earthquake.usgs.gov/4kids/

Step 4 Identify Your Building's Potential Weaknesses

Is Your House, Condo, or Apartment Strong Enough to Withstand an Earthquake?

Use the quiz on the next page to see if your home is likely to be so badly damaged in a future earthquake that people might be injured or that it would be unsafe to occupy. If your home scores above 17 on the quiz and has not been strengthened in the last few years, you probably should have a structural engineer evaluate it. The engineer will check to see if your home is strong enough to keep you and your family reasonably safe in an earthquake by looking for the following:

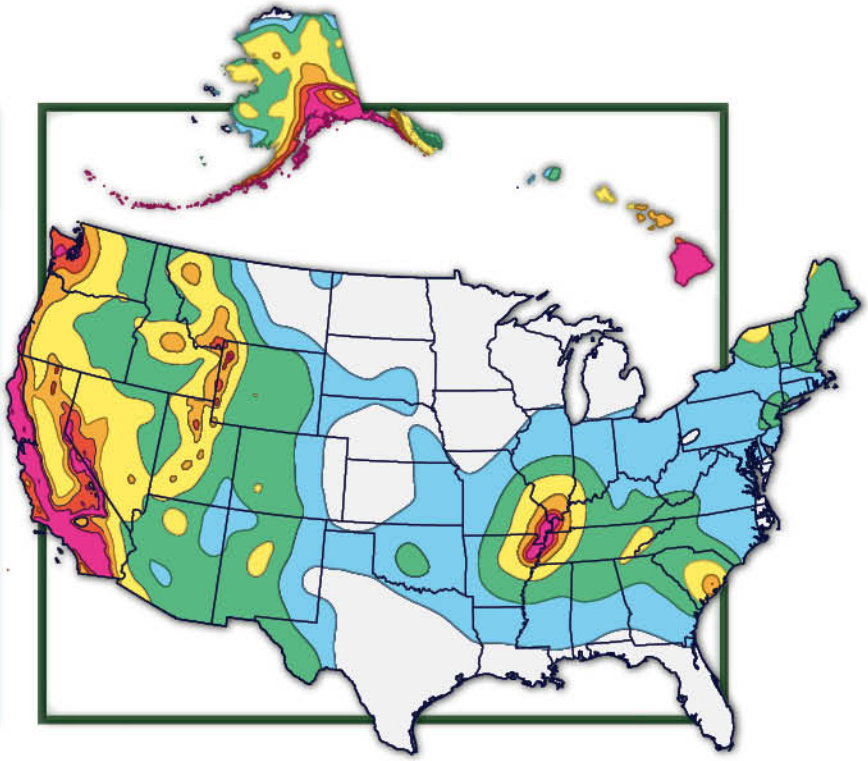
- Is your house properly connected to the foundation?
- Is there plywood on the exterior walls of your house?
- Are there anchors attaching the roof and floor systems to the walls?
- Is your house constructed out of unreinforced masonry?
- Do you have large openings like a garage door that may require better bracing?
- What is the condition of the mortar in your chimney?

The following quiz will help you to determine the adequacy of your house in resisting a seismic event. Once you have identified the areas requiring retrofitting, prioritize how and when to fix them and get started. Local building departments and the Structural Engineers Association (*http://www.seaint.org*) are excellent resources.

Don't be Fooled!

Earthquake Myth—
"We have good building codes, so we must have safe buildings."

The best building code in the world does nothing for buildings built before the code was enacted. Although building codes used in the Central United States have seismic provisions, many older buildings, particularly unreinforced masonry buildings, have not been retrofitted to meet updated codes. Retrofitting—fixing problems in older buildings—is the responsibility of a building's owner.



BEFORE A QUAKE

Structural Safety Quiz for Homes and Other Buildings

For each question write in the point value for your answer. Add up the points for your total score.

When was your home built?

Before 1970	6
1970–1980	3
After 1980	1

+

How many stories are in your home and how is it designed?

2 or more stories above grade with stepped floors, split levels, or large openings in floors	5
2 or more stories above grade with flat floors, no steps in the floor, and no large openings in floors	3
1 story rambler above grade	1

+

What is the construction material of the exterior walls?

Unreinforced masonry bearing walls	7
Wood or reinforced masonry with full-height brick veneer	3
Wood or reinforced masonry	1

+

What is the construction material of the foundation walls?

Stacked rock or brick, with basement	5
Stacked rock or brick, no basement	3
Concrete, with or without basement	1
Slab on grade, no basement	0

+

Where is your house located? (see map, facing page)

=

If your home scores 17 or more points on the quiz, consider having an engineer, architect, or contractor evaluate it.

Total points: ☐

Examples:

1. 1958, 1 story, unreinforced masonry, concrete foundation, Memphis: **6+1+7+1+8 = 23**
2. 1995, 2 story (flat), wood (brick veneer), concrete foundation, St. Louis: **1+3+3+1+5 = 13**
3. 2006, 2 story (large openings), wood, slab on grade, Little Rock: **1+5+1+0+3 = 10**

Step 5 Protect Yourself During Earthquake Shaking

The previous pages have concentrated on getting you ready for future earthquakes, but *what should you do when the shaking starts?*

If You Are Indoors...

DROP, COVER, AND HOLD ON. If you are not near a desk or table, drop to the floor against an interior wall and protect your head and neck with your arms.
Avoid exterior walls, windows, hanging objects, mirrors, tall furniture, large appliances, and cabinets filled with heavy objects.
Do not go outside until well after the shaking stops!

In bed

Hold on and stay there, protecting your head with a pillow. You are less likely to be injured staying where you are. Broken glass on the floor can cause injuries; be sure to put shoes on before stepping on the floor.

In a high-rise building

DROP, COVER, AND HOLD ON. Avoid windows. Do not use elevators. Do not be surprised if sprinkler systems or fire alarms activate.

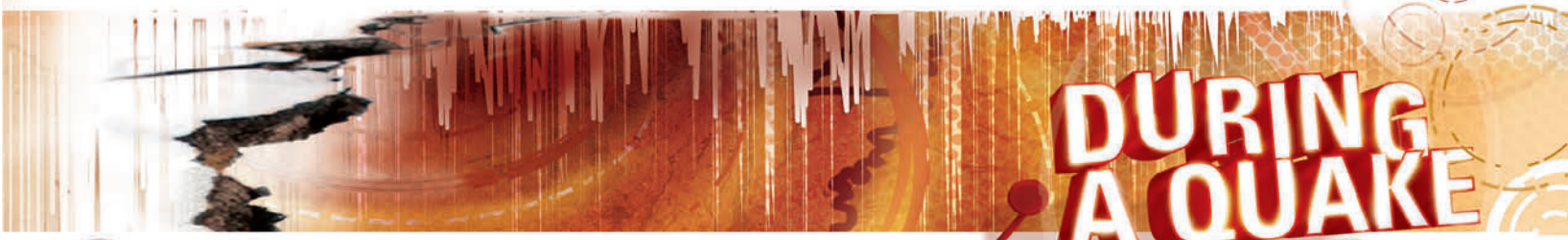
At work

DROP, COVER, AND HOLD ON. Know your workplace's earthquake safety plan and put it into action. When safe, move to a specified meeting location.

In a public building or theater

DROP, COVER, AND HOLD ON if possible. If in a theater seat, duck down and protect your head and neck with your arms. Don't try to leave until the shaking is over. Then walk out slowly, watching for fallen debris or anything that could fall on you during aftershocks.

DROP, COVER, AND HOLD ON —If you are indoors when you feel strong earthquake shaking, drop to the floor, take cover under a sturdy desk or table, and hold on to it firmly until ***the shaking stops.***



If You Are Outdoors...

Move to a clear area if you can do so safely; avoid buildings, power lines, trees, and other hazards. Always assume fallen power lines are live.

Near tall buildings

Windows, facades, and architectural details are often the first parts of a building to collapse. Get away from this danger zone when shaking starts. Take refuge in a safe building or an open space.

Driving

When able, safely pull over to the side of the road, stop, and set the parking brake. Avoid overpasses, bridges, power lines, signs, trees, and other things that might collapse or fall on the vehicle. Stay inside the vehicle until the shaking is over. If a power line falls on the vehicle, stay inside until a trained person removes the hazard.

In a stadium

Stay at your seat and protect your head and neck with your arms. Don't try to leave until the shaking is over. Then exit slowly, avoiding debris and watching for anything that could fall during aftershocks.

Below a dam

Dams can fail during a major earthquake. Catastrophic failure is unlikely, but if you are downstream from a dam, you should know flood-zone information and have an evacuation plan prepared. For more information about possible downstream flood areas, contact FEMA or your State water and dam safety office.

Don't be Fooled!

Earthquake Myth—
"The 'triangle of life' survival method is the best method to use inside a building to survive an earthquake."

False. The best survival method inside a building is to Drop, Cover, and Hold On under a table, desk, or chair, rather than trying to get into a survivable void next to a large, bulky object as advocated by the Triangle of Life method. The Drop, Cover, and Hold On survival method protects individuals from objects falling from walls and shelves. It also provides a level of protection from structural failures. If a table or desk is not available, sit down with your back against an interior wall, using your hands and arms to protect your head and neck.

Step 6

After the Earthquake
Check for Injuries and Damage

AFTERSHOCK?
Go back to STEP 5.

Once earthquake shaking has stopped,
follow your disaster preparedness plans (see STEP 2, page 28).
Most importantly:

Check for Injuries

NOTE: The manual in your first aid kit and the front pages of your telephone book have instructions on first aid measures.

- Check yourself for serious injuries before helping others. Protect your mouth, nose, and eyes from dust.
- If a person is bleeding, put direct pressure on the wound. Use clean gauze or cloth, if available.
- If a person is not breathing, administer rescue breathing.
- If a person has no pulse, begin CPR (cardiopulmonary resuscitation).
- Do not move seriously injured persons unless they are in immediate danger of further harm.
- Cover injured persons with blankets or additional clothing to keep them warm.

Check for Damage Causing Hazardous Conditions

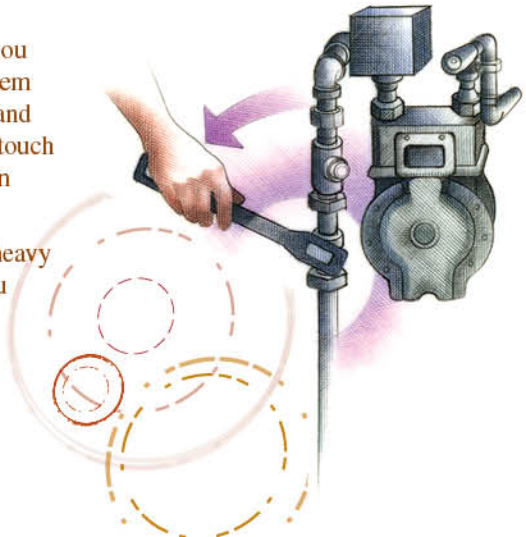
Fire—If possible, put out small fires in your home or neighborhood immediately. Call for help, but don't wait for the fire department.

Damaged electrical wiring—Shut off power at the main breaker switch if there is any damage to your home wiring. Leave the power off until the damage is repaired! (Your telephone book also has information on this topic.)

Downed utility lines—If you see downed power lines, consider them live or energized and keep yourself and others well away from them. Never touch downed power lines or any objects in contact with them!

Falling items—Beware of heavy items tumbling off shelves when you open closet and cupboard doors.

Gas leaks—Turn off the gas only if you suspect a leak because of broken pipes or you detect the odor or sound of leaking natural gas. Use a manual gas shut-off wrench to close your main gas valve by turning it counterclockwise. Don't turn gas back on by yourself—wait for the gas company! (Your telephone book has information on this topic.)



Spills—Use extreme caution; when in doubt, leave your home. Spilled medicines, drugs, or other relatively nontoxic substances can be cleaned up. Potentially harmful materials, such as bleach, lye, garden chemicals, paint, and gasoline or other flammable liquids should be isolated or covered with an absorbent material such as dirt or cat litter.

Damaged masonry—Stay away from brick chimneys and walls. They may be weakened and could topple during aftershocks. Don't use a fireplace with a damaged chimney, as this could start a fire or trap toxic gases in your home.

AFTER A QUAKE

If Your Home Is Seriously Damaged

If your home is structurally unsafe or threatened by a fire or other secondary disaster, you need to evacuate. However, shelters may be overcrowded and initially lack basic services, so do not leave home just because utilities are out of service or your home and its contents have suffered moderate damage.

If you evacuate, tell a neighbor and your family point-of-contact where you are going. Take the following, if possible, when you evacuate:

Bring to a shelter:

- ☐ Personal disaster supply kits (see STEP 3, page 30)
- ☐ Supply of water, food, and snacks
- ☐ Blanket, pillow, and air mattress or sleeping pad
- ☐ Change of clothing and a jacket
- ☐ Diapers, formula, food, and other supplies for infants
- ☐ A few family pictures or other small comfort items, such as dolls or teddy bears for children
- ☐ Personal identification and copies of household and health insurance information
- ☐ Books and games (especially for children)
- ☐ Towel and washcloth

Do not bring:

- Pets (service animals for people with disabilities are allowed—bring food for them)
- Large quantities of unnecessary clothing or other personal items
- Valuables that might be lost, stolen, or take up needed space

Step 7 When Safe, Continue to Follow Your Disaster Preparedness Plan

AFTERSHOCK?
Go back to STEP 5.

Once you have met the immediate needs of you and your family after a strong earthquake, continue to follow your disaster preparedness plan (see STEP 2, page 28).

The First Days after the Quake

In the days following a damaging quake, pay special attention to the following:

Safety first

- Do not reenter your home until you know it is safe.
- Be sure there are no gas leaks at your home before using open flames (lighters, matches, candles, or grills) or operating any electrical or mechanical device that could create a spark (light switches, generators, chain saws, or motor vehicles).
- Check for chemical spills, faulty electrical wiring, and broken water lines. Water in contact with faulty wiring is a shock hazard.
- Unplug broken or toppled light fixtures or appliances. These could start fires when electricity is restored.
- Never use the following indoors—camp stoves, kerosene or gas lanterns or heaters, gas or charcoal grills, or gas generators—as these can release deadly carbon monoxide gas or be a fire hazard in aftershocks.

Be in communication

- Turn on your portable or car radio and listen for information and safety advisories.
- Place all phones back on their cradles.
- Call your out-of-area contact, tell them your status, and then stay off the phone—emergency responders need the phone lines for life-saving communications.
- Check on your neighbors.

Check your food and water supplies

- If power is off, plan meals so as to use up refrigerated and frozen foods first. If you keep the door closed, food in your freezer may be good for a couple of days.
- If your water is off, you can drink from water heaters, melted ice cubes, or canned vegetables. Avoid drinking the water from swimming pools or hot tubs; use it to fight fires.

FEMA mobile homes being set up in Port Charlotte, Florida, to provide temporary housing for victims of Hurricane Charley (August 2004). Nearly a year after the storm, these trailers were still being used.
(Photo courtesy of the Federal Emergency Management Agency.)

AFTER A QUAKE

The First Weeks after the Earthquake

This is a time of transition. Although aftershocks may continue, you will now work toward getting your life, your home and family, and your routines back in order. Emotional care and recovery are just as important as healing physical injuries and rebuilding a home. Make sure your home is safe to occupy and not in danger of collapse in aftershocks. If you were able to remain in your home or return to it after a few days, you will have a variety of tasks to accomplish while reestablishing routines:

- If your gas was turned off, you will need to arrange for the gas company to turn it back on.
- If the electricity went off and then came back on, check your appliances and electronic equipment for damage.
- If water lines broke, look for water damage.
- Locate or replace critical documents that may have been misplaced, damaged, or destroyed.
- Contact your insurance agent or company to begin your claims process.
- Contact the Federal Emergency Management Agency (FEMA) to find out about financial assistance. To register with FEMA over the phone, call 1-800-621-FEMA (3362).
- If you cannot live at your home, set up an alternative mailing address with the post office.

If you can't stay in your home

The American Red Cross offers immediate emergency assistance with housing needs. The Red Cross also supports shelter operations prior to a Presidential declaration of a Federal disaster. Once a Presidential declaration has been issued, FEMA may activate the Assistance for Individuals and Households Program. This program includes:

- Home-repair cash grants; the maximum Federal grant available is $28,800 for all individual and family assistance.
- Housing assistance in the form of reimbursement for short-term lodging expenses at a hotel or motel.
- Rental assistance for as long as 18 months in the form of cash payment for a temporary rental unit or a manufactured home.
- If no other housing is available, FEMA may provide mobile homes or other temporary housing.

A Review of Money Matters: Financial Impacts of Earthquakes

Following an earthquake, disaster aid may not be immediately available, so you should plan ahead. If you have prepared a financial disaster recovery plan, you are more likely to recover successfully after a quake. Financial recovery planning resources are available from:

Operation Hope—Emergency Financial First Aid Kit
http://www.operationhope.org/smdev
American Red Cross—Disaster Recovery: A Guide to Financial Issues
http://www.redcross.org/preparedness/FinRecovery/
Federal Emergency Management Agency—Help After a Disaster: Applicant's Guide to the Individuals & Households Program
http://www.fema.gov/about/process
Small Business Administration—Disaster Assistance Loans
http://www.sba.gov/disaster_recov/index.html

Don't be Fooled!

Earthquake Myth—
"I don't need to worry about earthquakes—the Government will save me!"

Many people wrongly believe that the U.S. Government will take care of all their financial needs if they suffer losses in an earthquake. The truth is that Federal disaster assistance is only available if the President formally declares a disaster. Even if you do get disaster assistance, it is usually a loan that you must repay, with interest, in addition to mortgages and other financial obligations you still owe, even on damaged property. If you don't qualify for loans, grants may be available to you. However, these are only designed to meet your most immediate needs, not to replace your losses (see pages 22 and 23).

Your Financial Disaster Recovery Kit

After a damaging earthquake, you will need copies of essential financial documents, as well as emergency cash. Keep these items together, keep them current, and store them in a fire-proof document safe. Consider purchasing a home safe or renting a safe deposit box. Some essential items in your financial disaster recovery kit are:

- ☐ Birth certificates
- ☐ Marriage license/divorce papers and child custody papers
- ☐ Passports and driver's licenses
- ☐ Social security cards
- ☐ Naturalization papers and residency documents
- ☐ Military/veteran's papers
- ☐ Critical medical information
- ☐ Cash, in the event ATM or bank services are disrupted
- ☐ Certificates for stocks, bonds, and other investments
- ☐ Bank statements
- ☐ Credit card numbers
- ☐ A list of phone numbers for financial institutions and credit card companies where you have accounts
- ☐ Insurance policies
- ☐ An inventory of your household possessions
- ☐ Appraisals of valuable jewelry, art, antiques, and heirlooms
- ☐ Home improvement records
- ☐ A backup of critical files on your computer (also keep a copy at work)
- ☐ A list of names, phone numbers, and e-mail addresses of critical personal and business contacts
- ☐ Deeds, titles, and other ownership records for property such as homes, autos, RVs, and boats
- ☐ Powers of attorney, including health-care powers of attorney
- ☐ Wills or trust documents

For help in the first week after an earthquake, contact:

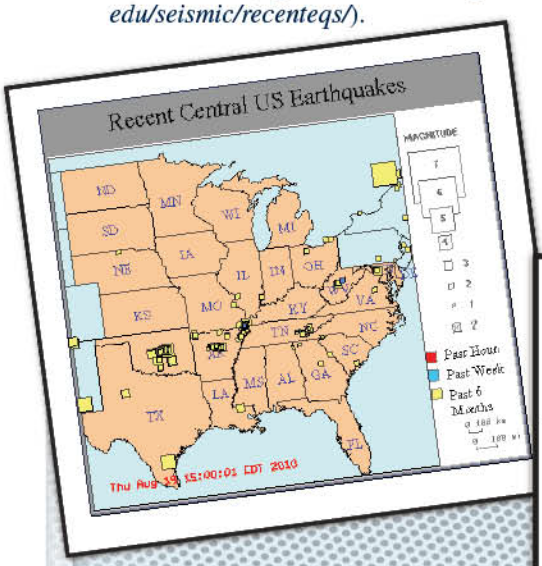
- Your county office of emergency services
- American Red Cross—*http://www.redcross.org/*
- Federal Emergency Management Agency (FEMA)—*http://www.fema.gov/assistance*

Earthquake Information on the Web

After an earthquake, knowing more about what just happened can reduce fears and help you understand what to expect next.

Location and magnitude of recent earthquakes

Within 5 to 10 minutes of an earthquake, the location and magnitude of the event are available at several Web sites, including the U.S. Geological Survey Earthquake Hazards Program (*http://earthquake.usgs.gov*) and the Center for Earthquake Research and Information (*http://www.ceri.memphis.edu/seismic/recenteqs/*).



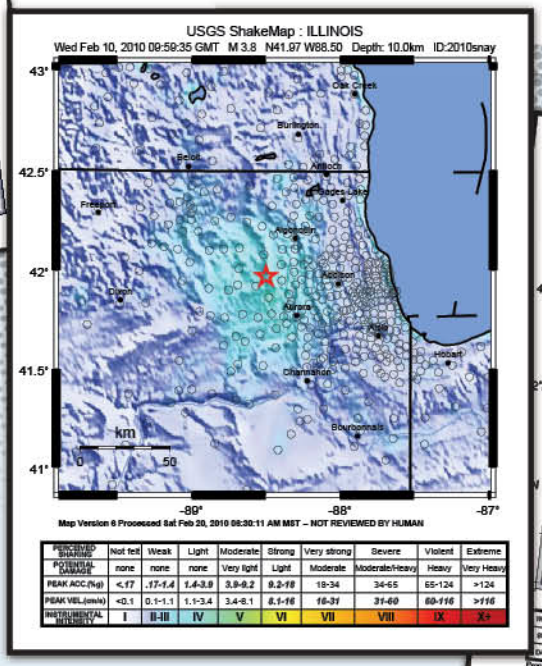
"ShakeMap"

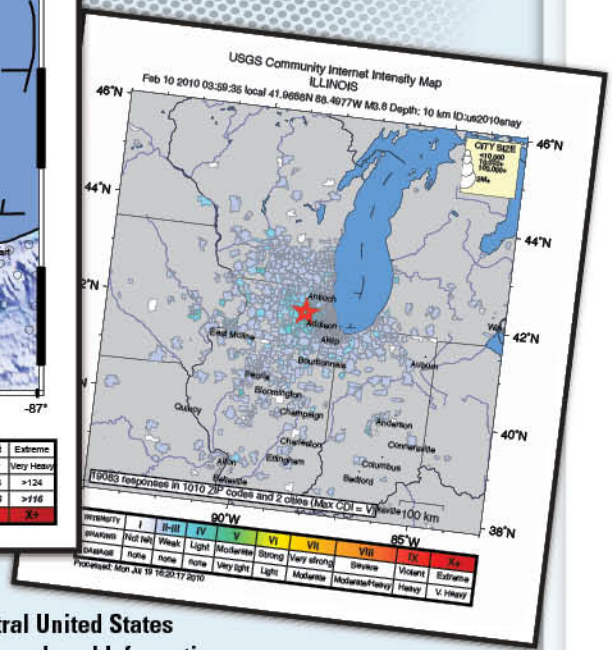
Within 10 to 15 minutes of most felt earthquakes (magnitude 3.0 and greater), a U.S. Geological Survey "ShakeMap" is posted on the Web. This map shows the range of shaking intensities across a region. Every earthquake has only a single magnitude, but the intensity of shaking can vary over the area in which the quake is felt.

ShakeMaps use data from seismic instruments to provide a rapid picture of where the strongest shaking occurred. These maps help to identify areas where a quake's impact is greatest and are used by emergency managers to speed disaster response. ShakeMaps are available at ***http://earthquake.usgs.gov/eqcenter/shakemap/.***

"Did You Feel It?"— Tell us what you felt!

Personal experiences of the effects of an earthquake are very valuable to scientists. When you have felt a quake, please report your observations by using a quick survey found on the U.S. Geological Survey "Did You Feel It?" Web site at ***http://earthquake.usgs.gov/dyfi/.*** When you fill out the survey, your observations of actual damage and shaking are combined with those of thousands of other people. The earthquake's shaking intensities, derived from these observations, are displayed by ZIP code on a "Community Internet Intensity Map."

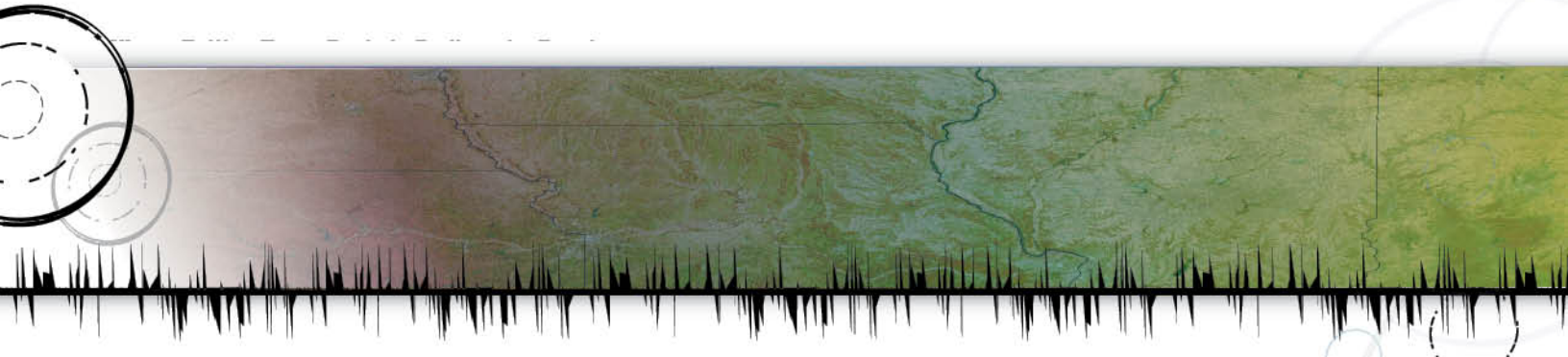




Who monitors Central United States earthquakes?

Seismic monitoring in the Central United States is conducted by the U.S. Geological Survey in partnership with the Center for Earthquake Research and Information at the University of Memphis and with support from participating States and universities in the region.

Left to right:
-Map of recent earthquakes in the Central United States from the Center for the Earthquake Research and Information.
-ShakeMap for the February 10, 2010, magnitude 3.8 earthquake west of Chicago, IL.
-Community Internet Intensity Map ("Did You Feel It?") for the February 10, 2010, Chicago earthquake. More than 19,000 people reported their observations on this quake online.



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Glossary

Aftershocks. Earthquakes that follow the largest shock of an earthquake sequence. They are smaller than the **mainshock** and can occur over a period of weeks, months, or years. In general, the larger the mainshock, the larger and more numerous the aftershocks and the longer they will continue.

Crust. Earth's outermost layer consisting of the upper parts of rigid oceanic and continental **tectonic plates**.

Epicenter. The point on Earth's surface above where an earthquake begins at depth in Earth's crust.

Fault. A fracture or crack in the Earth's **crust** along which the two sides slide past one another.

Fault rupture. The area of Earth through which fault movement occurs during an earthquake. For large earthquakes, the section of the **fault** that ruptures may be several hundred miles in length. Ruptures may or may not extend to the ground surface.

Fault scarp. A steep, linear break or slope formed where a **fault** ruptures the ground surface.

Fault segment. A part of a **fault** that is thought to rupture independently of other parts of the fault. One or more segments may rupture in a single earthquake.

Foreshock. An earthquake that precedes the largest quake (**mainshock**) of an earthquake sequence. Foreshocks may occur seconds to weeks before the mainshock. Not all mainshocks are preceded by foreshocks.

Intensity. The local severity of ground shaking during an earthquake in terms of its effects on the Earth's surface and on humans and their structures, measured on a numeric scale usually in Roman numerals. Several scales exist, but the ones most commonly used in the United States are the Modified Mercalli scale and the Rossi-Forel scale. An earthquake can have several intensities, depending on where you are in the affected area, but it has only one **magnitude**.

Landslide. A mass movement of soil, mud, and (or) rock down a slope.

Liquefaction. The process that occurs when an earthquake shakes wet sandy soil until it behaves like a liquid, allowing sand to "boil up" to the surface, buildings to sink, or sloping ground to move.

Magnitude (M). A number that represents the size of an earthquake, as determined from seismographic observations. An increase of one unit of magnitude (for example, from 4.6 to 5.6) corresponds approximately to a thirtyfold increase in energy released; a two-unit increase in magnitude—such as from 4.7 to 6.7—represents a thousandfold increase in energy. Earthquakes smaller than magnitude 2.5 generally are not felt by humans.

Mainshock. The largest quake of an earthquake sequence, possibly preceded by smaller **foreshocks** and commonly followed by **aftershocks**.

Modified Mercalli Intensity scale. See **Intensity**.

Normal fault. An inclined **fault** along which the upper side moves downward relative to the lower side.

Retrofit. Modifying equipment or structures already in use with more modern parts or systems. In terms of earthquake preparedness, strengthening an existing structure to improve its resistance to the effects of earthquakes.

Rift. A place where the Earth's **crust** is pulling apart, forming a central linear downfaulted segment, called a graben or rift valley, with parallel normal faulting and rift-flank uplifts on either side. Failed rifts are areas where continental rifting began but then failed to continue to the point of breakup.

Seiche. Waves "sloshing" in a lake as a result of earthquake ground shaking. Waves caused by a landslide into a reservoir or displacement of the lake bed are termed a surge.

Seismic hazard. The potential for damaging effects caused by earthquakes. The level of hazard depends on the **magnitude** and frequency of likely earthquakes, the distance from the **fault** that could cause earthquakes, and geologic conditions at a site.

Seismic risk. The chance of injury, damage, or loss resulting from seismic hazards. There is no risk, even in a region of high seismic hazard, if there are no people or property that could be injured or damaged by an earthquake.

Seismograph. A sensitive instrument that detects and records seismic waves generated by an earthquake.

Surface faulting (surface fault rupture). Propagation of an earthquake-generating **fault rupture** to the surface, displacing the surface and forming a **fault scarp**.

Tectonic plate. Earth's outer shell is composed of large, relatively strong plates that move relative to one another. Movements on the **faults** that define plate boundaries produce most earthquakes.

Tectonic subsidence. Downdropping and tilting of a basin floor on the downdropped side of a **fault** during an earthquake.

Temblor. Another word for earthquake.

Thrust fault. An inclined **fault** along which the upper side moves upward relative to the lower side. The Reelfoot fault is a good example.

Online Resources

New Madrid Bicentennial
http://newmadrid2011.org

Partners and Organizations

American Red Cross
http://www.redcross.org

Association of CUSEC State Geologists
http://www.cusec.org/about-cusec/cusec-associations/cusec-state-geologists.html

Center for Earthquake Research and Information (University of Memphis)
http://www.ceri.memphis.edu

Central U.S. Earthquake Consortium
http://www.cusec.org

Earthquake Country Alliance
http://earthquakecountry.info/

Federal Emergency Management Association
http://www.fema.gov/assistance

National Earthquake Hazards Reduction Program
http://www.nehrp.gov

Ready America
http://www.ready.gov/america

Southern California Earthquake Center
http://www.scec.org/

Structural Engineers Association
http://www.seaint.org

U.S. Geological Survey Earthquake Hazards Program
http://earthquake.usgs.gov

Information on Recent Earthquakes

Center for Earthquake Research and Information—Recent Central U.S. Earthquakes
http://www.ceri.memphis.edu/seismic/recenteqs

U.S. Geological Survey—Did You Feel It?
http://earthquake.usgs.gov/earthquakes/dyfi

U.S. Geological Survey—ShakeMaps
http://earthquake.usgs.gov/eqcenter/shakemap

Earthquake Preparedness

American Red Cross—Disaster Recovery: A Guide to Financial Issues
http://www.redcross.org/preparedness/FinRecovery

Federal Emergency Management Agency—Are You Ready
http://www.fema.gov/areyouready/earthquakes.shtm

Federal Emergency Management Agency—For Kids
http://www.fema.org/kids

Federal Emergency Management Agency—Help After a Disaster: Applicant's Guide to the Individuals & Households Plan
http://www.fema.gov/about/process

Operation Hope—Emergency Financial First Aid Kit
http://www.operationhope.org/smdev

Putting Down Roots in Earthquake Country—7 Steps to an Earthquake Resilient Business
http://www.earthquakecountry.info/roots/7StepsBusiness2008.pdf

QuakeSmart—Your Business, Your Investment, Your Choice
http://www.quakesmart.org

Ready.gov—Ready America
http://www.ready.gov/america

Ready.gov—Ready Business
http://www.ready.gov/business

Small Business Association—Disaster Assistance Loans
http://www.sba.gov/disaster_recov/index.html

U.S. Geological Survey—Earthquakes for Kids
http://earthquake.usgs.gov/4kids

U.S. Geological Survey—Reducing Hazards in the Central and Eastern United States
http://earthquake.usgs.gov/regional/ceus

U.S. Geological Survey—U.S. Earthquake Information by State
http://earthquake.usgs.gov/earthquakes/states